Airplanes, Airships, Aircraft Engin

AIRPLANES, AIRSHIPS,
AIRCRAFT ENGINES

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BY

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FOREWORD

This book has been prepared with the idea in view of furnishing a good practical knowledge of aircraft to the Naval Service. The nomenclature contained herein was compiled by the National Advisory Committee on Aeronautics, which is without question the best authority on the subject in this country. The writer is indebted to the above committee for the courtesy extended him in authorizing its publication in this book. The writer is also indebted to Lieutenant J. W. Iseman, U.S.N.R.F., and Ensign J. C. Eames, U.S.N. R.F., for valuable assistance rendered in preparation of data on instruments and aircraft engines.

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NOTE

General Order No. 57, dated July 2, 1921, signed by the Secretary of the Navy, states that "Report No. 91 of the National Advisory Committee, entitled 'Nomenclature for Aeronautics' has been adopted as the official nomenclature for Aeronautics for use of the Army and Navy Air Services."

This nomenclature is contained in this book.

A. TUCKER.

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CHAPTER I

Nomenclature for Aeronautics Alphabetically

Aerodynamic pitch.—(See Pitch.)

Aerofoil.—A winglike structure, flat or curved, designed to obtain reaction upon its surfaces from the air through which it moves.

Aerofoil section.—A section of an aerofoil made by a plane parallel to the plane of symmetry of the aerofoil and to the normal direction of motion.

Aeronaut.—The pilot of an aerostat.

Aerostat.—An aircraft which embodies a container filled with a gas lighter than air and which is sustained by the buoyancy of this gas; e.g., airship, balloon.

Aerostatics.—The science which relates to the buoyancy and behavior of lighter-than-air craft.

Aerostation.—The operation of balloons and airships. Corresponds to aviation, but refers to lighter-than-air craft.

Aileron.—A hinged or pivoted movable auxiliary surface of an airplane, usually part of the trailing edge of a wing, the primary function of which is to impress a rolling moment on the airplane. (Fig. 1.)

Air scoop.—A projecting cowl, which, by using the dynamic pressure of the relative wind or slip-stream, serves to maintain air pressure in the interior of the ballonet of an aerostat. (Fig. 2.)

Aircraft.—Any form of craft designed for the navigation of the air—airplanes, airships, balloons, helicopters, kites, kite balloons, ornithopters, gliders, etc.

Airdome.—A field providing facilities for aircraft to land and take off and equipped with hangars, shops, and a supply depot for the storage, maintenance, and repair of aircraft.

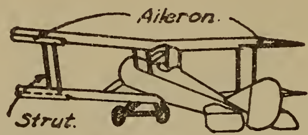


FIG. 1.

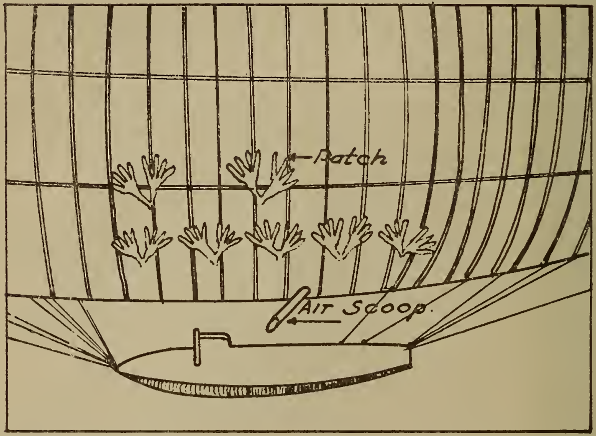
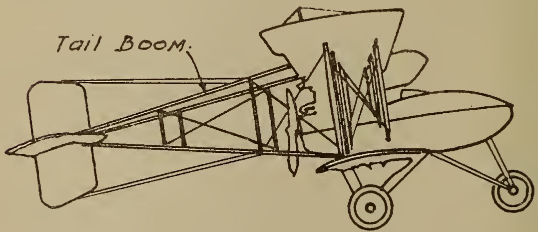


FIG. 2.



PUSHER BIPLANE.

FIG. 3

Airplane.—A form of aircraft heavier than air which obtains support by the dynamic reaction of the air against the wings and which is driven through the air by a screw propeller. This term is commonly used in a more restricted sense to refer to airplanes fitted with landing gear suited to operation from the land. If the landing gear is suited to operation from the water, the term "seaplane" is used. (See definition.)

Pusher.—A term commonly applied to a single engine airplane with the propeller in the rear of the main supporting surfaces. (Fig. 3.)

Tandem.—An airplane with two or more sets of wings of substantially the same area (not including the tail unit) placed one in front of the other and on about the same level.

Tractor.—A term commonly applied to a single engined airplane with the propeller forward of the main supporting surfaces. (Fig. 4.)

Airship.—A form of aerostat provided with a propelling system and with means of controlling the direction of movement.

Nonrigid.—An airship whose form is maintained by the pressure of the contained gas.

Rigid.—An airship whose form is maintained by a rigid structure contained within the envelope.

Semirigid.—An airship whose form is maintained by means of a rigid or jointed keel and by gas pressure.

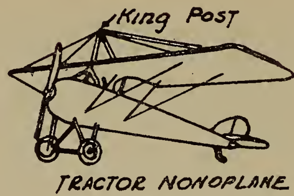
Air speed.—(See Speed.)

Air-speed indicator.—(See Indicator.)

Altimeter.—An aneroid barometer, mounted on an aircraft, whose dial is marked in feet, yards, or meters.

Anemometer.—Any instrument for measuring the velocity or force of the wind.

Angle, critical.—The angle of attack at which the flow about



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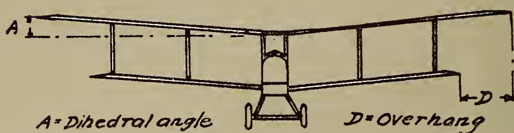


FIG. 5.

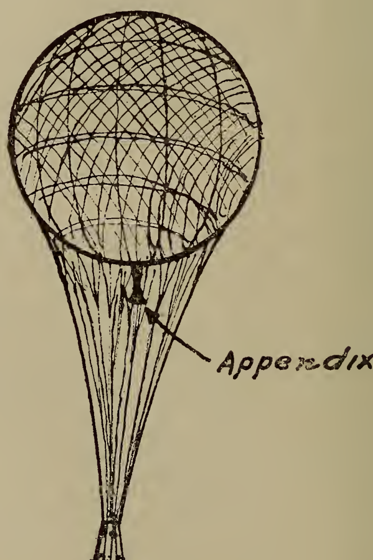


FIG. 6.

an aerofoil changes abruptly, with corresponding abrupt changes in the lift and drag coefficients. An aerofoil may have two or more critical angles, one of which almost always corresponds to the angle of maximum lift.

Angle, dihedral.—The main supporting surfaces of an airplane are said to have a dihedral angle when both right and left wings are upwardly or downwardly inclined to a horizontal transverse line. The angle is measured by the inclination of each wing to the horizontal. If the inclination is upward, the angle is said to be positive; if downward, negative. The several main supporting surfaces of an airplane may have different amounts of dihedral. (Fig. 5.)

Angle, downwash.—The acute angle through which the air stream relative to the airplane is deflected by an aerofoil. It is measured in a plane parallel to the plane of symmetry.

Angle, gliding.—The acute angle which the flight path makes with the horizontal when descending in still air under the influence of gravity alone; i.e., without power from the engine.

Angle, landing.—The angle of attack of the main supporting surfaces of an airplane at the instant of touching the ground in a three point landing; i.e., the angle between the wing chord and the horizontal when the machine is resting on the ground in its normal position.

Angle of attack.—The acute angle between the direction of the relative wind and the chord of an aerofoil; i.e., the angle between the chord of an aerofoil and its motion relative to the air. (This definition may be extended to any body having an axis.)

Angle of incidence (in directions for rigging).—In the process of rigging an airplane some arbitrary definite line in the airplane is kept horizontal; the angle of incidence

of a wing, or of any aerofoil, is the angle between its chord and this horizontal line, which may be the line of the upper longerons of the fuselage or nacelle or the thrust line.

Angle of pitch.—The angle between two planes defined as follows: One plane includes the lateral axis of the aircraft and the direction of the relative wind; the other plane includes the lateral axis and the longitudinal axis. (In normal flight the angle of pitch is, then, the angle between the longitudinal axis and the direction of the relative wind.) This angle is positive when the nose of the aircraft rises.

Angle of propeller blade setting.—The angle which the chord of a propeller section makes with a plane perpendicular to the axis of the propeller. This angle varies along the blade, increasing as the boss is approached.

Angle of roll, or angle of bank.—The angle through which an aircraft must be rotated about its longitudinal axis in order to bring its lateral axis into a horizontal plane.

Angle of tail setting.—The acute angle between the chord of the wings of an airplane and the chord of the tail plane.

Angle of yaw.—The angle between the direction of the relative wind and the plane of symmetry of an aircraft. This angle is positive when the aircraft turns to the right.

Angle of zero lift.—(See Zero lift angle.)

Antidrag wires.—(See Wires.)

Antilift wires.—(See Wires.)

Apparent pressure.—The excess of pressure inside the envelope of an aerostat over the atmospheric pressure. In the case of an airship, the excess of pressure is measured at the bottom of the envelope unless otherwise specified.

Appendix.—The tube at the bottom of a balloon, used for inflation. In the case of a spherical balloon it also serves

to increase the "head" of gas, and so to build up an internal pressure sufficient to keep the envelope from being pulled out of shape by the weight of the basket. (Fig. 6.)

Aspect ratio.—The ratio of span to mean chord of an aerofoil.

Aspect ratio of propeller.—The ratio of propeller diameter to maximum blade width.

Attack, angle of.—(See Angle.)

Attitude.—The attitude of an aircraft is determined by the inclination of its axes to a "frame of reference" fixed to the earth, i.e., the attitude depends entirely on the position of the aircraft as seen by an observer on the ground.

Automatic valve.—An automatic escape and safety valve for the purpose of regulating internal pressure in an aerostat.

Aviator.—The operator or pilot of heavier-than-air craft. This term is applied regardless of the sex of the operator.

Axes of an aircraft.—Three fixed lines of reference; usually centroidal and mutually rectangular. (Fig. 7.)

The principal longitudinal axis in the plane of symmetry, usually parallel to the axis of the propeller, is called the longitudinal axis; the axis perpendicular to this in the plane of symmetry is called the normal axis; and the third axis, perpendicular to the other two, is called the lateral axis. In mathematical discussions the first of these axes, drawn from front to rear, is called the X axis; the second, drawn upward, the Z axis; and the third, running from right to left, the Y axis.

Balanced surface.—(See Surface.)

Ballonet.—A small balloon within the interior of a balloon or airship for the purpose of controlling the ascent or descent and for maintaining pressure on the outer envelope so as to prevent deformation.

Balloon.—A form of aerostat deriving its support in the air from the buoyancy of the air displaced by an envelope,

the form of which is maintained by the pressure of a contained gas lighter than air, and having no power plant or means of controlling the direction of flight in the horizontal plane.

Barrage.—A small captive balloon, raised as a protection against attacks by airplanes.

Captive.—A balloon restrained from free flight by means of a cable attaching it to the earth.

Kite.—An elongated form of captive balloon, fitted with tail appendages to keep it headed into the wind, and usually deriving increased lift due to its axis being inclined to the wind. A Caquot balloon is of this type. (Fig. 8.)

Nurse.—A small balloon made of heavy fabric, employed as a portable means for storing gas. Sometimes one is so connected as to automatically allow for the expansion or contraction of the gas in an aerostat when on the ground.

Pilot.—A small balloon sent up to show the direction of the wind by observations of its flight with theodolites.

Sounding.—A small balloon sent aloft without passengers but with registering meteorological and other instruments.

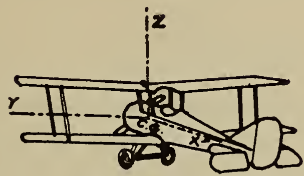
Balloon bed.—A mooring place on the ground for a captive balloon.

Balloon fabric.—(See Fabric.)

Bank.—To incline an airplane laterally. Right bank is to incline the airplane with the right wing down. Also used as a noun to describe the position of an airplane when its lateral axis is inclined to the horizontal.

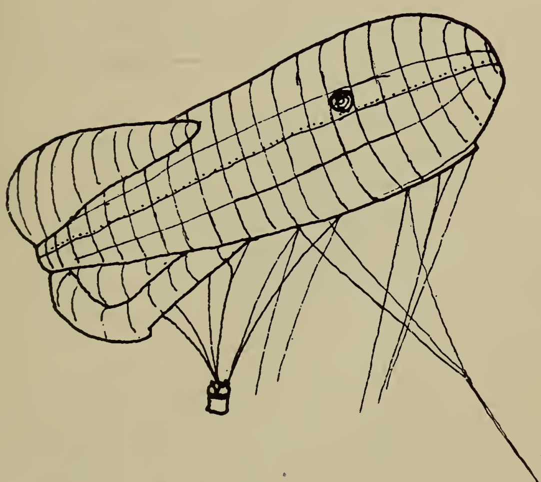
Bank, angle of.—(See Angle of roll.)

Barograph.—An instrument used to make a permanent record of variations in barometric pressure. In aeronautics the charts on which the records are made some-



Axes of an Airoplane

FIG. 7.



Kite Ballon.

FIG. 8.

times indicate altitudes directly instead of barometric pressure.

Barrage balloon.—(See Balloon.)

Barrel roll.—An aerial maneuver in which a complete revolution about the longitudinal axis is made, the direction of flight being approximately maintained.

Basket.—The car suspended beneath a balloon for passengers, ballast, etc.

Bay.—The cubic section of a truss included between two transversely adjacent sets of struts of an airplane. The first bay is the one closest to the plane of symmetry.

Biplane.—A form of airplane whose main supporting surface is divided into two parts, superimposed.

Blade back.—The markedly convex surface of a propeller blade which corresponds to the upper surface of an aerofoil.

Blade face.—The surface of a propeller blade, flat or slightly cambered near the tips, which corresponds to the lower surface of an aerofoil.

Blade setting, angle of.—(See Angle.)

Blade width ratio.—The ratio of the width of a propeller blade at any point to the circumference of the circle along which that point travels when the propeller is rotating and the airplane is held stationary. When used without qualifying terms, it refers to the ratio of the maximum blade width to the circumference of the circle swept by the propeller.

Boat seaplane.—(See Seaplane.)

Bonnet.—The appliance, having the form of a parasol, which protects the valve of a spherical balloon against rain.

Boss.—The central portion of an airscrew. The portion in which the hub is mounted.

Bow stiffeners.—Rigid members attached to the bow of a nonrigid or semirigid envelope to reinforce it against the

pressure caused by the motion of the airship. (Sometimes called nose stiffeners.)

Bridle.—A sling of cordage which has its ends attached to the envelope of a balloon or airship and a rope or cable running from an intermediate point.

Bulkhead.—A transverse structural member of a fuselage or nacelle, continuous around the periphery.

Buoyancy.—The upward force exerted on a lighter-than-air craft due to the air which it displaces.

Center of.—The center of volume of the gas container or the center of gravity of the gas (envelope) of a balloon or airship.

Gross.—The total upward force on an aerostat at rest; the total volume multiplied by the difference of density of the air and the contained gas.

Positive and negative.—The positive or negative difference between the buoyancy and the weight of a balloon or airship. The unbalanced force which causes ascent or descent.

Cabane.—A pyramidal or prismoidal framework to which wire or cable stays are secured.

Camber.—The convexity or rise of the curve of an aerofoil from its chord, usually expressed as the ratio of the maximum departure of the curve from the chord to the length of the chord. "Top camber" refers to the top surface of an aerofoil and "bottom camber" to the bottom surface; "mean camber" to the mean of these two.

Camber ratio.—The ratio of the maximum ordinate of a propeller section is its chord.

Capacity.—The cubic contents or volume of an aerostat.

Captive balloon.—(See Balloon.)

Caquot balloon.—(See Balloon, kite.)

Car.—The nacelle of an airship.

Ceiling:

Absolute.—The maximum height above sea level which a given aircraft can approach asymptotically, assuming standard air conditions.

Service.—The height above sea level at which a given aircraft ceases to rise at a rate higher than a small specified one (100 feet per minute in United States Air Service). This specified rate may be different in the services of different countries.

Cell.—The entire structure of the wings and wing trussing on one side of the fuselage of an airplane, or between fuselage or nacelles, where there are more than one.

Center of pressure of an aerofoil section.—The point in the chord of an aerofoil section, prolonged if necessary, through which at any given attitude the line of action of the resultant air force passes.

Chord:

Of an aerofoil section.—The line of a straightedge brought into contact with the lower surface of the section at two points. In the case of an aerofoil having double convex camber the straight line joining the leading and trailing edges. (These edges may be defined, for this purpose, as the two points in the section which are farthest apart. (Fig. 9.)

Length.—The length of the projection of the aerofoil section on its chord.

Chord, mean, of a wing.—The quotient obtained by dividing the wing area by the extreme dimension of the wing projection at right angles to the chord.

Climb, rate of.—The vertical component of the air speed of an aircraft; i.e., its vertical velocity with reference to the air.

Cockpit.—The open spaces in which the pilot and passengers are accommodated. A cockpit is never completely housed in.

Concentration ring:

Airship.—A metal ring to which several rigging lines are brought from the envelope and from which one or more lines also lead to the car.

Free balloon.—A hoop to which are attached the ropes suspending the basket and to which the net is also secured.

Parachute.—A hoop to which the rigging of the parachute is attached and also the line sustaining the passenger.

Consumption per B.H.P. hour.—The quantity of fuel or oil consumed per hour by an engine running at ground level divided by the brake horsepower developed, unless specifically stated otherwise.

Control column or yoke.—A control lever with a rotatable wheel mounted at its upper end. (See Control stick.) Pitching is controlled by fore-and-aft movement of the column; rolling, by rotation of the wheel. "Wheel control" is that type of control in which such a column or yoke is used.

Control stick.—The vertical lever by means of which certain of the principal controls of an airplane are operated. Pitching is controlled by a fore-and-aft movement of the stick, rolling by side-to-side movement. "Stick control" is that type of control in which such a stick is used.

Controls.—A general term applying to the means provided to enable the pilot to control the speed, direction of flight, attitude, and power of an aircraft.

Cord.—A species of wire made up of several strands (usually 7) twisted together as in a rope, each of the strands, in turn, being made up of several (usually 19) individual wires.

Cowling.—The metal covering which houses the engine and sometimes a portion of the fuselage or nacelle as well.

Critical angle.—(See Angle.)

Cross-wind force.—The component perpendicular to the lift and to the drag of the total force on an aircraft due to the air through which it moves.

Crow's-foot.—A system of diverging short ropes for distributing the pull of a single rope.

Damping factor.—The percentage of damping in one period.

Dead load.—(See Load.)

Dihedral angle.—(See Angle.)

Disk area.—The total area swept by a propeller, i.e., the area of a circle having a diameter equal to the propeller diameter.

Dischargeable weight.—The excess of the gross buoyancy over the dead load, the crew and such items of equipment as are essential to enable an airship to fly and land safely.

Dive.—A steep glide.

Divergence.—A disturbance which increases without oscillation.

Dope, airplane.—A general term applied to the material used in treating the cloth surface of airplane members to increase strength, produce tautness, and act as a filler to maintain airtightness.

Downwash angle.—(See Angle.)

Drag.—The component parallel to the relative wind of the total force on an aerofoil or aircraft due to the air through which it moves.

In the case of an airplane, that part of the drag due to the wings is called "wing resistance;" that due to the rest of the airplane is called "structural" or "parasite resistance."

Drag rope.—The rope dropped by an airship in order to allow it to be secured by a landing party.

Drag strut.—A compression member of the internal bracing system of an aerofoil.

Drag wires.—(See Wires.)

Drift.—The angular deviation from a set course over the earth, due to cross currents of wind, hence, "drift meter."

Drift meter.—An instrument for the measurement of the angular deviation of an aircraft from a set course, due to cross winds.

Drip flap.—A strip of fabric attached by one edge to the envelope of an aerostat so that rain runs off its free edge instead of dripping into the basket or car. The drip flap assists also to keep the suspension ropes dry and nonconducting.

Dry weight.—The weight of an engine, including carburetors, propeller-hub assembly, and ignition system complete, but excluding exhaust manifolds.

Dynamic factor.—The ratio between the load carried by any part of an aircraft when accelerating or when otherwise subjected to abnormal conditions and the load carried in normal flight.

Dynamic lift.—(See Lift.)

Effective pitch.—(See Pitch.)

Elevator.—A movable auxiliary surface of an airplane, usually attached to the tail plane, the function of which is to impress a pitching moment on the aircraft. (Fig. 10.)

Empennage.—Same as tail unit.

Envelope.—The outer covering of a rigid airship; or, in the case of a balloon or a nonrigid airship, the bag which contains the gas.

Equator.—The largest horizontal circle of a spherical balloon.

Fabric, balloon.—The finished material, usually rubberized, of which balloon or airship envelopes are made.

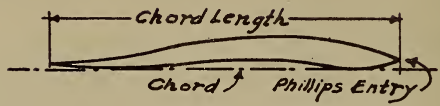


FIG. 9

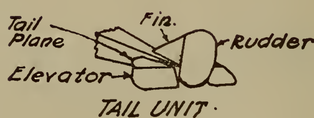


FIG. 10

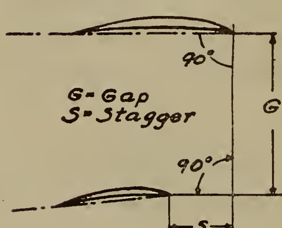


FIG. 11

Biased.—Plied fabric in which the threads of the plies are at an angle to each other.

Parallel.—Plied fabric in which the threads of the plies are parallel to each other.

Factor, dynamic.—(See Dynamic factor.)

Factor of safety.—The ratio of the ultimate strength of a member to the maximum possible load occurring under conditions specified.

Fairing.—A member whose primary function is to produce a smooth outline and to reduce head resistance or drag.

Fins.—Small stationary surfaces, substantially vertical, attached to different parts of aircraft, in order to promote stability; for example, tail fins, skid fins, etc. Fins are sometimes adjustable. (Fig. 10.)

Skid fins.—Fore and aft vertical surfaces, usually placed well out toward the tips of the upper plane, designed to provide the vertical keel-surface required for stability.

Fins, kite balloon.—The air inflated lobes intended to keep the balloon headed into the wind.

Fire wall.—A metal plate, so set as to isolate from the engine the other parts of the airplane structure, and thus to reduce the risk from a backfire.

Fitting.—A generic term for any small metal part used in the structure of an airplane.

Flight path.—The path of the center of gravity of an aircraft with reference to the earth.

Float.—A completely inclosed water-tight structure attached to an aircraft in order to furnish it buoyancy when in contact with the surface of the water. In float seaplanes the crew is carried in a fuselage or nacelle separate from the float.

Floating seaplane.—(See Seaplane.)

Flotation gear.—An emergency landing gear attached to an airplane, which will permit of safe landing on the water

and provide buoyancy when resting on the surface of the water.

Flying boat.—(See Seaplane.)

Free-flight testing.—The conduct of special flight tests of a scientific nature, as contrasted with performance testing.

Full load.—(See Load.)

Fuselage.—The elongated structure, of approximately steamline form, to which are attached the wings and tail unit of an airplane. In general, it is designed to hold the passengers.

Fuselage, length of.—The distance from the nose of the fuselage (including the engine bed and radiator, if present) to the after end of the fuselage, not including the control and stabilizing surfaces.

Gap.—The shortest distance between the planes of the chord of the upper and lower wings of a biplane, measured along a line perpendicular to the chord of the upper wing at any designated point of its entering edge. (Fig. 11.)

Geometrical pitch.—(See Pitch.)

Glide, to.—To descend at a normal angle of attack without engine power sufficient for level flight, the propeller thrust being replaced by a component of gravity along the line of flight.

Glider.—A form of aircraft similar to an airplane, but without any power plant. Gliders are used chiefly for sport.

Gliding angle.—(See Angle.)

Gore.—The portion of the envelope of a balloon or airship included between two adjacent meridian seams.

Gross buoyancy.—(See Buoyancy.)

Ground cloth.—Canvas placed on the ground to protect a balloon.

Ground speed.—(See Speed.)

Handling truck.—A truck, mounted on wheels or sliding on ways, on which airplanes or seaplanes may be placed to facilitate moving them about and carrying them to and from their hangars.

Hangar.—A shelter for housing aircraft.

Helicopter.—A form of aircraft whose support in the air is derived from the vertical thrust of propellers.

Hog (Airship).—A distortion of the envelope in which the axis becomes convex upward or both ends droop.

Horn.—The operating lever of a control sufrace of an aircraft, e.g., aileron horn, rudder horn, elevator horn.

Horsepower of an engine, maximum.—The maximum horsepower which can be safely maintained for periods not less than five minutes.

Horsepower of an engine, normal.—The highest horsepower which can be safely maintained for long periods.

Hull (airship).—The main structure of a rigid airship, consisting of a covered elongated framework which incloses the gas bags and which supports the cars and equipment.

Hull (seaplane).—The portion of a boat seaplane which furnishes buoyancy when in contact with the surface of the water, to which the main supporting surfaces and other parts are attached, and which contains accommodations for the crew.

Incidence, angle of.—(See Angle.)

Inclinometer:

Absolute.—An instrument giving the attitude of an aircraft with reference to true gravity.

Relative.—An instrument giving the attitude of an aircraft with reference to apparent gravity. Such instruments are sometimes incorrectly referred to as banking indicators.

Indicator, air-speed.—An anemometer mounted on an air-

craft for the purpose of indicating the speed of the aircraft.

True air-speed indicator.—An instrument, usually working on the principle of the Biram or Robinson anemometers, which gives the true air speed, independent of density.

Apparent air-speed indicator.—An instrument, usually dependent on pressure measurements, the readings of which vary with the density of the air.

Indraft.—The drawing in of air from in front of a propeller by the action of the rotating blades. The indraft velocity relative to the propeller is somewhat higher than that of the undisturbed air at most points of the propeller disk.

Inspection window.—A small transparent window in the envelope of a balloon or in the wing of an airplane to allow inspection of the interior.

Jackstay.—A longitudinal rigging provided to maintain the correct distance between the heads of various riggings on an airship.

Keel.—A member or assembly of members which provides longitudinal strength to an airship of rigid or semirigid type. In the case of a rigid airship the keel is usually an elaborately trussed girder and may be inclosed within the envelope or may project beyond (usually below) the regular cross-sectional form of the envelope.

Articulated.—A keel made up of a series of members hinged together at their ends.

King post.—The main compression member of a trussing system applied to a member subject to bending. (Fig. 4.)

Kite.—A form of aircraft without other propelling means than the towline pull, whose support is derived from the force of the wind moving past its surface.

Kite balloon.—(See Balloon.)

Laminated wood.—Wooden parts made up by gluing or otherwise fastening together individual wood planks or laminations with the grain substantially parallel.

Landing angle.—(See Angle.)

Landing field.—A field of such a nature as to permit of airplanes landing or taking off.

Landing gear.—The understructure of an aircraft designed to carry the load when in contact with the land or water.

Leading edge.—The foremost edge of an aerofoil or propeller blade.

Length, chord.—(See Chord.)

Length, fuselage.—(See Fuselage.)

Length, over-all.—(See Over-all.)

Lift.—The component of the total air force which is perpendicular to the relative wind and in the plane of symmetry. It must be specified whether this applies to a complete aircraft or parts thereof. (In the case of an airship this is often called "dynamic lift.")

Lift wires.—(See Wires.)

Load:

Dead.—The structure, power plant, and essential accessories of an aircraft. Included in this are the water in the radiator, tachometer, thermometer, gauges, airspeed indicators, levels, altimeter, compass, watch and hand starter, and also, in the case of an aerostat, the amount of ballast which must be carried to assist in making a safe landing.

Full.—The total weight of an aircraft when loaded to the maximum authorized loading of that particular type.

Useful.—The excess of the full load over the dead load of the aircraft itself. Therefore useful load includes the crew and passengers, oil and fuel, ballast, electric-light installation, chart board, detachable gun mounts, bomb storage and releasing gear, wireless apparatus, etc.

Load factor.—The ratio of the ultimate strength of a member to the load under horizontal steady rectilinear flight conditions.

Lobes.—Inflated bags at the stern of an elongated balloon, designed to give it directional stability. Also used to denote the sections into which the envelope is sometimes (e.g., in the Astra-Torres) divided by the tension of the internal rigging.

Longeron.—A fore-and-aft member of the framing of an airplane fuselage or nacelle, usually continuous across a number of points of support. (Fig. 12.)

Loop.—An aerial maneuver in which the airplane describes an approximately circular path in the plane of the longitudinal and normal axes, the lateral axis remaining horizontal, and the upper side of the airplane remaining on the inside of the circle.

Main supporting surface.—(See Surface.)

Margin of power.—(See Power.)

Mean chord of a wing.—(See Chord.)

Mean chord of a combination of wings.—(See Chord.)

Mean span.—(See Span, mean.)

Minimum speed.—(See Speed.)

Monocoque.—A type of fuselage which is constructed by wrapping strips of veneer around formers, and in which the veneer is primarily depended on to carry stresses arising in the fuselage.

Monoplane.—A form of airplane which has but one main supporting surface extending equally on each side of the body.

Mooring harness.—The system of bands of tape over the top of a balloon to which are attached the mooring ropes.

Multiplane.—A form of airplane whose main supporting surface is divided into four parts, superimposed.

Nacelle.—The inclosed shelter for passengers or for a power plant. A nacelle is usually shorter than a fuselage, and does not carry the tail unit.

Net.—A rigging made of ropes and twine on spherical balloons which supports the weight of the basket, etc., distributing the load over the entire upper surface of the envelope.

Nonrigid airship.—(See Airship.)

Nose cap.—A cap used to reinforce the bow stiffeners of an airship.

Nose heavy.—The condition of an aircraft in which, in any given condition of normal flight, the nose tends to drop if the longitudinal control is released; i.e., the condition in which the pilot has to exert a pull on the control stick or column to maintain the given condition.

Nurse balloon.—(See Balloon.)

Ornithopter.—A form of aircraft deriving its support and propelling force from flapping wings.

Oscillation, phugoid.—A long period oscillation characteristic of the disturbed longitudinal motion of an airplane.

Oscillation, stable.—An oscillation which tends to die out.

Oscillation unstable.—An oscillation of which the amplitude tends to increase.

Over-all length.—The distance from the extreme front to the extreme rear of an aircraft, including the propeller and the tail unit.

Overhang.—One-half the difference in the span of any two main supporting surfaces of an airplane. The overhang is positive when the upper of the two main supporting surfaces has the larger span. (Fig. 5.)

Pancake, to.—To "level off" an airplane higher than for a normal landing, causing it to stall and descend with the wings at a very large angle of attack and approximately without bank, on a steeply inclined path.

Panel aerostat.—The unit piece of fabric of which the envelope of an aerostat is made.

Panel airplane.—A portion of a wing of an airplane which is constructed entirely separately from the rest of the wing, and which is attached to the remainder by bolts and fittings.

Parachute.—An apparatus used to retard the descent of a falling body by offering resistance to motion through the air; usually made of light fabric with no rigid parts.

Parasite resistance.—(See Drag.)

Patch, airship.—A strengthened or reinforced flap of fabric, of variable form according to the maker, which is cemented to the envelope and forms an anchor by which some portion of the machine is attached to the envelope. (Fig. 2.)

Performance.—The maximum and minimum speeds and rate of climb at various altitudes, the time to climb to these altitudes, and the ceiling constitute the performance characteristic of an airplane.

Performance testing.—The process of determining the performance characteristics of an airplane.

Period.—The time taken for a complete oscillation.

Permeability.—The measure of the rate of diffusion of gas through intact balloon fabric; usually expressed in cubic meters per square meter per 24 hours.

Phillips' entry.—A reversal of curvature of the lower surface of an aerofoil near the leading edge. The result is to decrease the drag and provide more depth for the front spar. (Fig. 9.)

Phugoid oscillation.—(See Oscillation.)

Pilot balloon.—(See Balloon.)

Pitch of propeller:

Pitch, aerodynamic.—The distance a propeller would have to advance in one revolution in order that the torque might be zero.

Pitch, effective.—The distance an aircraft advances along its flight path for one revolution of the propeller.

Pitch, geometrical.—The distance an element of a propeller would advance in one revolution if it were turning in a solid nut; i.e., if it were moving along a helix of slope equal to the angle between the chord of the element and a plane perpendicular to the propeller axis. The mean geometrical pitch of a propeller, which is a quantity commonly used in specifications, is the mean of the geometrical pitches of the several elements.

Pitch, standard.—The "pitch of a propeller" is usually stated as the geometrical pitch taken at two-thirds of the radius.

Pitch, virtual.—The distance a propeller would have to advance in one revolution in order that there might be no thrust.

Pitch, angle of.—(See Angle.)

Pitch slip.—(See Slip.)

Pitch speed.—(See Speed.)

Pitot tube.—A tube with an end open square to a fluid stream. It is exposed with the open end pointing upstream to detect an impact pressure. It is usually associated with a coaxial tube surrounding it, having perforations normal to the axis for indicating static pressure; or there is such a tube placed near it and parallel to it, with a closed conical end and having perforations in its side. The velocity of the fluid can be determined from the difference between the impact pressure and the static pressure, as read by a suitable gauge. This instrument is often used to determine the velocity of an aircraft through the air. (Fig. 13.)

Plywood.—A product formed by gluing together two or more layers of wood veneer.

Power, margin of.—The difference between the power available at any given speed and in air of given density and the power required for level flight under the same conditions. The best rate of climb at any altitude depends on the maximum margin of power.

Power loading.—The weight per horsepower, computed on a basis of full load and of power in air of standard density unless otherwise stated.

Pressure nozzle.—The apparatus which, in combination with a gauge, is used to measure the pressure due to speed through the air. Includes both Pitot and Venturi tubes. Pressure nozzles of various types are also used in yawmeters and other instruments.

Proofing.—Material applied to the fabric of an aerostat at the time of manufacture to protect it against weather or to prevent the passage of gas.

Propeller, pusher.—A propeller which is placed at the rear end of its shaft and pushes against the thrust bearing.

Propeller, tractor.—A propeller which is placed at the forward end of its shaft and pulls on the thrust bearing.

Purity of a gas.—The percentage, by number of molecules, of the light gas used for inflation, such as hydrogen, to all the gases within the container.

Pusher airplane.—(See Airplane.)

Pusher propeller.—(See Propeller.)

Quadruplane.—A form of airplane whose main supporting surface is divided into four parts, superimposed.

Race rotation.—The rotation of the air influenced by a propeller. This rotation is much more marked in the slip stream than in front of the propeller.

Rake.—The cutting away of the wing tip at an angle so that the main supporting sufraces seen from above will appear of trapezoidal form. The amount of rake is measured by the angle between the straight portion of

the wing-tip outline and the plane of symmetry. The rake is positive when the trailing edge is longer than the leading edge.

Rake, blade.—The angle which the line joining the centroids of the sections of a propeller blade makes with a plane perpendicular to the propeller shaft. The rake is positive when the blades are thrown forward.

Rate of climb.—The vertical component of the air speed of an aircraft; i.e., its vertical velocity with reference to the air.

Rate-of-climb indicator.—An instrument indicating the vertical component of the velocity of an aircraft. Most rate-of-climb meters depend on the rate of change of the atmospheric pressure.

Relative wind.—The motion of the air with reference to a moving body. Its direction and velocity, therefore, are found by adding two vectors, one being the velocity of the air with reference to the earth, the other being equal and opposite to the velocity of the body with reference to the earth.

Resistance derivatives.—Quantities expressing the variation of the forces and moments on aircraft due to disturbance of steady motion. They form the experimental basis of the theory of stability, and from them the periods and damping factors of aircraft can be calculated. In the general case there are 18 translatory and 18 rotary derivatives.

Rotary.—Resistance derivatives expressing the variation of moments and forces due to small increases in the rotational velocities of the aircraft.

Translatory.—Resistance derivatives expressing the variation of moments and forces due to small increases in the translatory velocities of the aircraft.

Reverse turn.—A rapid maneuver to reverse the direction of flight of an airplane, made by a half loop and half roll in either sequence.

Revolutions, maximum.—The maximum number of revolutions per minute that may be maintained for periods not less than 5 minutes.

Revolutions, normal.—The highest number of revolutions per minute that may be maintained for long periods.

Rib.—(See Wing rib.)

Rigger.—One who is employed in assembling and aligning aircraft.

Rigging.—The assembling and aligning of an aircraft.

Right-hand engine.—An engine the final power delivery shaft of which rotates clockwise when viewed by an observer looking along the engine toward the power delivery end.

Righting moment.—A moment which tends to restore an aircraft to its previous attitude after any small rotational displacement.

Rigid airship.—(See Airship.)

Rip cord.—The rope running from the rip panel of a balloon or nonrigid airship to the basket, the pulling of which tears off the rip panel and causes immediate deflation.

Rip panel.—A strip in the upper part of a balloon or nonrigid airship which is torn off when immediate deflation is desired.

Roll, angle of.—(See Angle.)

Rudder.—A hinged or pivoted surface used for the purpose of impressing yawing moments on an aircraft; i.e., for controlling its direction of flight. (Fig. 10.)

Rudder bar.—The foot bar by means of which the rudder is operated.

Rudder torque.—The twisting effect exerted by the rudder on the fuselage, due to the relative displacement of the center of pressure of the rudder. The product of the

rudder area by the distance from its center of area to the center line of the fuselage may be used as a relative measure of rudder torque.

Safety, factor of.—(See Factor of Safety.)

Safety loop.—A loop formed immediately outside the conical reversing bag through which the valve rope emerges from the bottom of an aerostat. Before the automatic valve can be opened by the aid of the valve rope the fastening of the safety loop is torn off by a strong pull on the valve rope from the nacelle.

Seaplane.—A particular form of airplane designed to rise from and land on the water.

Boat seaplane, or flying boat.—A form of seaplane having for its central portion a boat which provides flotation. It is often provided with auxiliary floats or pontoons. (Fig. 14.)

Float seaplane.—A form of seaplane in which the landing gear consists of one or more floats or pontoons (Fig. 15.)

Semirigid airship.—(See Airship.)

Serpent.—A short, heavy trail rope.

Shock absorber.—A spring or elastic member, designed to prevent the imposition of large accelerations on the fuselage, wings, and other heavy concentrated weights. Shock absorbers are usually interposed between the wheels, floats, or tail skid, and the remainder of the airplane to secure resiliency in landing and taxi-ing.

Shock-absorber hysteresis.—The ratio of the work absorbed in the shock absorber during one complete cycle to the total energy transmitted to the shock absorber during the first half of the cycle.

Shutters.—The adjustable blinds or vanes which are used to control the amount of air flowing through the radiator and so to regulate the temperature of the cooling water.

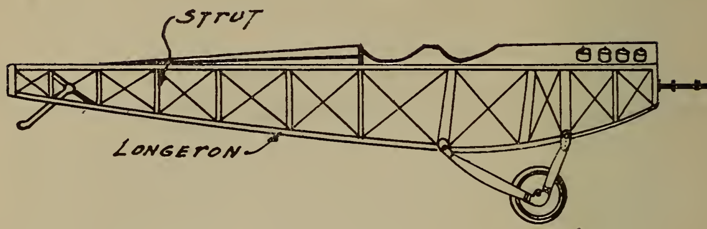


FIG. 12

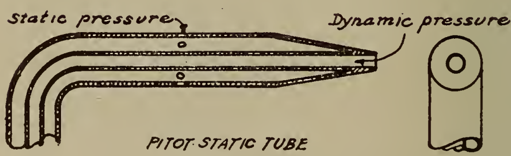


FIG. 13

BOAT SEAPLANE

FIG. 14

Side slipping.—Sliding with a component of velocity along the lateral axis which is inclined and in the direction of the lower end of that axis. When it occurs in connection with a turn it is the opposite of skidding.

Skid fins.—(See Fins.)

Skidding.—Sliding sidewise away from the center of curvature when turning. It is usually caused by banking insufficiently and is the opposite of side slipping.

Skids.—Runners used as members of the landing gear and designed to aid the aircraft in landing or taxi-ing.

Tail skid.—A skid used to support the tail when in contact with the ground.

Wing skid.—A skid placed near the wing-tip and designed to protect the wing from contact with the ground.

Skin friction.—The tangential component of the fluid force at a point on a surface. It depends on the viscosity and density of the fluid, the total surface area and the roughness of the surface of the object.

Slip.—The difference between the effective pitch and the mean geometrical pitch. Slip is usually expressed as a percentage of the mean geometrical pitch.

Slip stream.—The stream of air behind a propeller.

Soar, to.—To fly without engine power and without loss of altitude. Lightly loaded gliders will soar in rising currents of air.

Sounding balloon.—(See Balloon.)

Span, or spread.—The maximum distance laterally from tip to tip of an airplane inclusive of ailerons, or the lateral dimension of an aerofoil.

Speed:

Air.—The speed of an aircraft relative to the air.

Ground.—The horizontal component of the velocity of an aircraft relative to the earth.

Speed, minimum.—The lowest speed which can be maintained in level flight, with any throttle setting whatever.

Speed, pitch.—The product of the mean geometrical pitch by the number of revolutions of the propeller in unit time; i.e., the speed the aircraft would make if there were no slip.

Spin.—An aerial maneuver consisting of a combination of roll and yaw, with the longitudinal axis of the airplane inclined steeply downward. The airplane descends in a helix of large pitch and very small radius, the upper side of the airplane being on the inside of the helix, and the angle of attack on the inner wing being maintained at an extremely large value.

Spinner.—A fairing, usually made of sheet metal and roughly conical or paraboloid in form which is attached to the propeller boss and revolves with it.

Spiral instability.—The instability on account of which an airplane tends to depart from straight flight, by a combination of side slipping and banking, the latter being always too great for the turn.

Splice (of a wooden member).—A joint of two or more pieces of wood in which one piece overlaps the other in such a manner as to maintain the strength.

Spread.—(See Span.)

Stability:

Static stability.—A machine is statically stable if, when slightly displaced by rotation about its center of gravity (as in wind tunnel experimentation), moments come into play which tend to return the machine to its normal attitude.

Dynamical stability.—A machine is dynamically stable if, when displaced from steady motion in flight, it tends to return to that steady state of motion.

In a general way, the difference between static stability and dynamical stability is that the former depends on restoring moments and the latter on damping factors.

Automatic.—Stability dependent upon movable control surfaces. The term "automatic stability" is usually applied to those cases in which the control surfaces are automatically operated by mechanical means.

Directional.—Stability with reference to rotations about the normal axis; i. e., a machine possessing directional stability in its simplest form is one for which Nv is negative. Owing to symmetry, directional stability is closely associated with lateral stability.

Inherent.—Stability of an aircraft due solely to the disposition and arrangement of its fixed parts; i.e., that property which causes it, when disturbed, to return to its normal attitude of flight without the use of the controls or the interposition of any mechanical device.

Lateral.—Stability with reference to disturbances involving rolling, yawing, or side-slipping; i.e., disturbances in which the position of the plane of symmetry of the aircraft is affected.

Longitudinal.—Stability with reference to disturbances in the plane of symmetry; i.e., disturbances involving pitching and variations of the longitudinal and normal velocities.

Stabilizer.—(See Tail Plane.)

Stabilizer, mechanical.—A mechanical device to stabilize the motion of an aircraft. Includes gyroscopic stabilizers, pendulum stabilizers, inertia stabilizers, etc.

Stable oscillation.—(See Oscillation.)

Stagger.—The amount of advance of the entering edge of an upper wing of biplane, triplane, or multiplane over that of a lower, expressed as percentage of gap. It is considered positive when the upper wing is forward and

is measured from the entering edge of the upper wing along its chord to the point of intersection of this chord with a line drawn perpendicular to the chord of the upper wing at the entering edge of the lower wing, all lines being drawn in a plane parallel to the plane of symmetry. (Fig. 11.)

Stagger wires.—(See Wires.)

Stalling.—A term describing the condition of an airplane which from any cause has lost the relative air speed necessary for control.

Standard pitch.—(See Pitch.)

Static thrust.—The thrust developed by a propeller when the aircraft is held stationary on the ground.

Station.—A term used to denote the location of framing attachment in a fuselage or nacelle (strut points in a trussed fuselage, bulkhead points in a veneer fuselage.)

Statoscope.—An instrument to detect the existence of minute changes of atmospheric pressure, and so of small vertical motions of an aircraft.

Stay.—A wire or other tension member; for example, the stays of the wing and body trussing.

Step.—A break in the form of the bottom of a float or hull designed to assist in securing a dynamic reaction from the water.

Stick control.—(See Control Stick.)

Strand.—A species of wire made up of several individual wires twisted together. (There are usually 19 wires—a single wire as core, an inner layer of 6 wires, and an outer layer of 12.)

Streamline.—The path of a small portion of a fluid, supposed continuous, commonly taken relative to a solid body with respect to which the fluid is moving. The term is commonly used only of such paths as are not eddying, but the distinction should be made clear by the context.

Streamline flow.—The condition of continuous flow of a fluid, as distinguished from eddying flow.

Streamline form.—A fair form intended to avoid eddying and to preserve streamline flow.

Strut.—A member of a truss frame designed to carry compressive loads. For instance, the vertical members of the wing truss of a biplane (interplane struts) and the short vertical and horizontal member separating the longerons in the fuselage. (Figs. 1 and 12.)

Strut, drag.—(See Drag strut.)

Surface.—An aerofoil used for sustentation or control or to increase stability. Applies to the whole member, and not to one side only.

Balanced.—A surface, such as a rudder, aileron, etc., part of which is in front of its pivot.

Surface, main supporting.—A pair of wings, extending on the same level from tip to tip of an airplane; i.e., a triplane has three main supporting surfaces. The main supporting surfaces do not include any surfaces intended primarily for control or stabilizing purposes.

Suspension band.—The band around a balloon or airship to which are attached the main bridle suspensions of the basket or car.

Suspension bar.—The bar used for the concentration of basket suspension ropes in captive balloons.

Sweep back.—The angle, measured in a plane parallel to the lateral axis and to the chord of the main planes, between the lateral axis of an airplane and the entering edge of the main planes. (Fig. 16.)

Tail boom.—A spar or outrigger connecting the tail surfaces and main supporting surfaces. Usually used on pushers. (Fig. 3.)

Tail cups.—A steadying device attached by lines at the rear of certain types of elongated captive balloons. Some-

. FLOAT SEAPLANE .

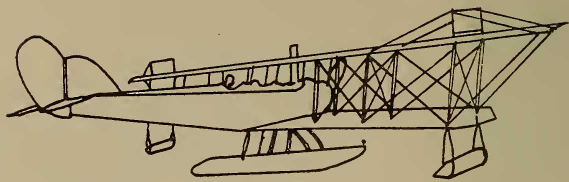


FIG. 15

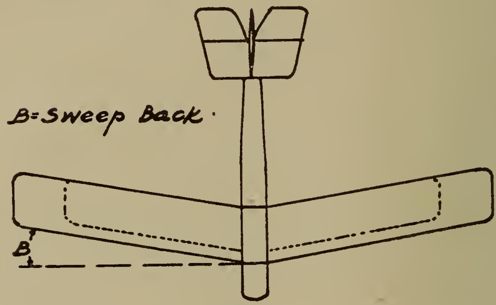


FIG. 16.

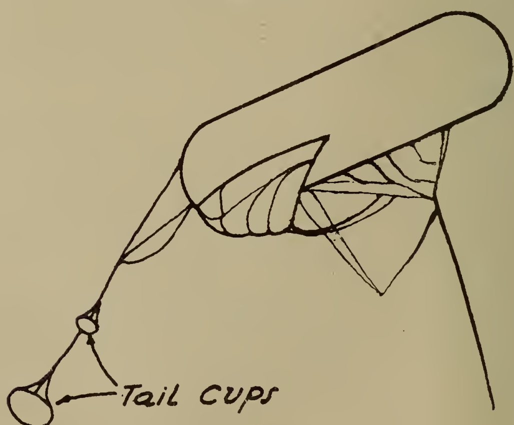


FIG. 17

what similar to a sea anchor. (Fig. 17.) Lobes have replaced tail cups to a large extent.

Tail droop.—A deformation of the airship in which the axis bends downward at the after end.

Tail heavy.—The condition of an aircraft in which, in any given condition of normal flight the nose tends to rise if the longitudinal control is released; i.e., the condition in which the pilot has to exert a push on the control stick or column to maintain the given condition.

Tail plane.—A stationary horizontal, or nearly horizontal, tail surface, used to stabilize the pitching motion. Often called "stabilizer." (Fig. 10.)

Tail setting, angle of.—(See Angle.)

Tail skid.—(See Skids.)

Tail slide.—The rearward motion which certain airplanes may be made to take after having been brought into a stalling position.

Tail unit.—The tail surfaces of an aircraft.

Tandem airplane.—(See Airplane.)

Taxi, to.—To run an airplane over the ground, or a seaplane on the surface of water, under its own power.

Toggle.—A short crossbar of wood or metal, having a shouldered groove, which is fitted at the end of a rope at right angles to it. It is used for obtaining a quickly detachable connection with an eye at the end of another rope. (Fig. 18.)

Tractor airplane.—(See Airplane.)

Tractor propeller.—(See Propeller.)

Trail rope.—The long trailing rope attached to a spherical balloon, to serve as a brake and as a variable ballast.

Trailing edge.—The rearmost edge of an aerofoil or propeller blade.

Trajectory band.—A band of webbing carried in a curve over the top of the envelope of an airship to distribute

the stresses due to the suspension. The use of trajectory bands was introduced in the Parseval airships. (Fig. 19.)

Triplane.—A form of airplane whose main supporting surface is divided into three parts, superimposed.

Turn indicator.—An instrument showing when the direction of the line of flight or the direction of the projection of that line on a horizontal plane is altering, and in its more refined forms, giving the rate of turn, in terms either of the angular velocity or of the radius of curvature.

Unstable oscillation.—(See Oscillation.)

Useful load.(—See Load.)

Valve, automatic.—(See Automatic Valve.)

Veneer.—Thin sheets or strips of wood.

Venturi tube.—A short tube with flaring ends and a constriction between them, so that, when fluid flows through it, there will be a suction produced in a side tube opening into the constricted throat. This tube, when combined with a Pitot tube or with one giving static pressure, forms a pressure nozzle, which may be used as an instrument to determine the speed of an aircraft through the air. (Fig. 21.)

Virtual pitch.—(See Pitch.)

Warp, to.—To change the form of a wing by twisting it. Warping is sometimes used to maintain the lateral equilibrium of an airplane.

Wash.—The disturbance in the air produced by the passage of an aerofoil.

Washin.—A permanent increase in the angle of attack near the tip of the wing.

Washout.—A permanent decrease in the angle of attack near the tip of the wing.

Weight, dischargeable.—(See Dischargeable Weight.)

Weight, dry.—(See Dry Weight.)

Weight per horsepower.—The dry weight of an engine divided by the normal horsepower developed at ground level.

Wheel control.—(See Control Column.)

Width ratio, total (propeller blade.—The product of blade width ratio by number of blades.

Wind, relative.—(See Relative Wind.)

Wind tunnel.—An elongated inclosed chamber, including means for the production of a substantially steady air current through the chamber. Models of aircraft or other objects are supported in the center of the airstream and their resistance and other characteristics when exposed to an air current of known velocity are determined. The term includes those laboratories in which, as in the Eiffel type, there is an experimental chamber of much larger cross-section than the air current.

Windmill.—A small air-driven turbine with blades similar to those of a propeller exposed on an aircraft, usually in the slip stream, and used to drive such auxiliary apparatus as gasoline pumps and radio generators.

Window, inspection.—(See Inspection window.)

Wing.—The portion of a main supporting surface of an airplane on one side of the plane of symmetry; e.g., a biplane has four wings.

Wing loading.—The weight carried per unit area of supporting surface. The area used in computing the wing loading should include the ailerons, but not the tail plane or elevators.

Wing resistance. (See Drag.)

Wing rib.—A fore-and-aft member of the wing structure of an airplane, used to give the wing section its form and to transmit the load from the fabric to the spars. (Fig. 20.)

Rib compression.—A heavy rib designed to have the above functions and also to act as a strut opposing the pull of the wires in the internal drag truss. (Fig. 20.)

Rib, form.—An incomplete rib, frequently consisting only of a strip of wood extending from the leading edge to the front spar, which is used to assist in maintaining the form of the wing where the curvature of the aerofoil section is sharpest. (Fig. 20.)

Wing skid.—(See Skids.)

Wing spars.—The principal transverse structural elements of the wing assembly of an airplane. The load is transmitted from the ribs to the spars, and thence to the lift and drag trusses. (Fig. 20.)

Wing truss.—The framing by which the wing loads of an airplane are transmitted to the fuselage; comprises struts, wires, or tie-rods, and spars.

Wire.—In aeronautics refers specifically to hard-drawn solid wire.

Wires, antidrag.—Wires designed primarily to resist forces acting parallel to the planes of the wings of an airplane and in the same direction as the direction of flight.

Wires, antilift.—Wires in an airplane intended mainly to resist forces in the opposite direction to the lift, and to oppose the lift wires and prevent distortion of the structure by overtightening of those members.

Wires, drag.—All wires designed primarily to resist forces acting parallel to the planes of the wings of an airplane and opposite to the direction of flight.

Internal drag wires are concealed inside the wings.

External drag wires run from the wing cell to the nose of the fuselage or some other part of the machine.

Wires, lift.—the wires which transmit the lift on the outer portion of the wings of an airplane in toward the fuselage or nacelle. These wires usually run from the top of an

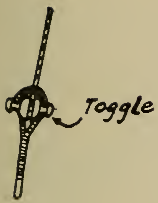


FIG. 18.

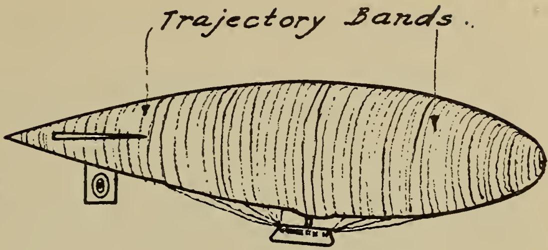


FIG. 19

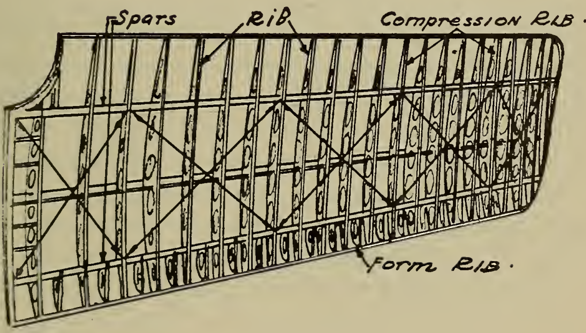


FIG. 20.

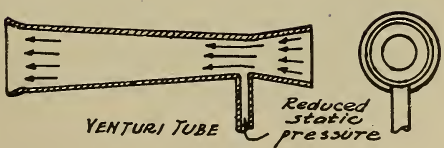


FIG. 21.

interplane strut to the bottom of the strut next nearer the fuselage.

Wires, stagger.—Wires connecting the upper and lower surfaces of an airplane, and lying in planes substantially parallel to the plane of symmetry.

Yaw, angle of.—(See Angle.)

Yawing.—Angular motion about the normal axis.

Yawmeter.—An instrument giving by direct reading the angle of yaw.

Yoke.—(See Control column.)

Zero lift angle.—The angle between the chord and the relative wind when the lift is zero.

Zero lift line.—The position in the plane of an aerofoil section of the line of action of the resultant air force when the position of the section is such that the lift is zero.

Zoom, to.—To climb for a short time at an angle greater than that which can be maintained in steady flight, the machine being carried upward at the expense of its stored kinetic energy. This term is sometimes used by pilots to denote any sudden increase in the upward slope of the flight path.

CHAPTER II

Explanations and Definitions of Various Other Terms Used in Connection with Aircraft, Etc.

Q. How many kinds of resistance are there to an airplane in flight?

A. Two kinds of resistance, wing resistance and all other resistances being known as parasite resistance.

Q. How many kinds of stabilities are there?

A. Seven, as follows: Static, Automatic, Inherent, Dynamical, Directional, Longitudinal and Lateral. (See Nomenclature for definition of each.)

Q. Which way does the center of pressure travel when a machine is in a climb?

A. The center of pressure travels forward until machine is climbing at too great an angle when the center of pressure travels rapidly towards the trailing edge and the machine will go into a stall.

Q. What are the results obtained by the gap being of the same distance as the length of the chord?

A. All things considered, the best results are obtained when gap equals chord. In order to eliminate interference entirely the gap should be 1.25 the length of chord. This would necessitate longer struts, longer load and lift wires, thereby increasing resistance as well as adding additional weight.

Q. What are the advantages and disadvantages of stagger?

A. The advantage of stagger is that the lift-drift are both increased by about 5 per cent. It is said the best method of stagger is to place the upper leading edge about two-fifths the length of chord in advance of the leading edge of the lower plane. This improvement is equivalent to that which would accrue if the biplane spacing of the gap was 1.25 per cent of the chord. An additional advantage is that it offers a better range of vision to the occupants. The disadvantage is that the strength of inclined struts to vertical load is decreased.

Q. What is center of gravity?

A. The point of a body about which all portions are balanced.

Q. What is center of lift?

A. The mean of all the centers of pressure.

Q. What is the center of pressure?

A. A line taken across the surface, transverse to the direction of motion and about which all the air forces may be said to balance, or through which they may be said to act.

Q. What is center of thrust?

A. A point or line along which the thrust of the propellers is balanced. (Center line of propeller.)

Q. What is the usual aspect ratio used?

A. The span is usually five to eight times the chord, the ratio of 6 to 1 being generally used, and the higher ratios given increase the efficiency of a wing because the loss of efficiency due to the air spilling off the wing tips is reduced by increasing the aspect ratio.

Q. What is propeller torque?

A. The effect of the reaction of the revolving propeller upon the equilibrium of the airplane is to cause a banking couple unless twin propellers are used. The amount of this couple is well within the pilot's control and it is only its variation which requires attention.

Q. What is a variable load?

A. A variable load consists of fuel and oil. This load is located near the center of gravity so as to have the least effect on the stability of the machine due to variability.

Q. What is meant by caviation?

A. Effect of revolving a propeller at an excessive speed for its pitch and diameter, creating a "hole" so to speak. The fuel, water, or air is carried around by the blades of the propeller in the same plane instead of being thrust back.

Q. What is a castellated nut?

A. One that is slotted to take a cotter pin passing through a hole in the bolt. So called from its resemblance to an ancient castle wall.

Q. What is meant by clockwise?

A. An engine that turns its shaft to the right (direct drive), or in the same direction as a clock hand rotates.

Q. What is meant by anti-clockwise?

A. An engine that turns its shaft to the left when viewed from the propeller end. Also termed a left handed engine.

Q. What is meant by critical speed?

A. Rate of travel at which an aeroplane just propels and sustains itself in the air.

Q. What is lee-way?

A. Movement at an angle to the course being steered, caused by the lateral drift of the atmosphere or by centrifugal force acting on the airplane in rounding a turn; also the angular deviation from a set course over the earth, due to cross currents of wind, also called drift.

Q. What is a pylon?

A. A pole placed on an aviation field to mark the course, also a mast or pillow serving as a marker of a course. Captive balloons are also used as pylons.

Q. What is spotting?

A. Noting the fall of shells from an airplane or balloon and reporting to the batteries necessary corrections in the range.

Q. What is dynamic thrust?

A. The work done by the propeller in forcing the airplane ahead. It equals the weight of the mass of air acted upon per second, the slip velocity in feet per second.

Q. What is meant by the term decalage?

A. This is the difference between the degrees of the angle of incidence in the upper and lower planes, in other words, if the upper plane has three (3) degrees angle of incidence, and the lower plane has two (2) degrees angle of incidence, it would be stated that the machine would have one (1) degree of decalage.

Q. What is meant by the term cathedral angle?

A. This is just the opposite of dihedral angle, and in some later type machines is placed in the lower wings of planes.

Q. What is an engine section panel?

A. The engine section panel is the panel directly above the fuselage or boat. This section usually contains a gravity tank for supplying gasoline to the engine.

Q. What are sidewalk panels?

A. Sidewalk panels are the lower panels adjacent to the hull of a flying boat or the fuselage of a pontoon type machine. They are portable in some types of machines, and in others they are built over the sidewalk beams, which in turn are built into the boat (and are not portable.) They derive their name from the fact that it is necessary in most instances to walk on same in getting in and out of the machine. Sometimes they are wholly covered with veneer for additional strength, and in other cases, only a section is covered with veneer to walk upon.

Q. What is an intermediate panel?

A. An intermediate panel is the panel adjacent and connected to the sidewalk panel in the lower plane, which in turn has the lower outer plane connected to the outer end of the intermediate panel; in the top plane the intermediate panel connects to engine section panel on inboard end, and to the outer end is connected the upper outer panel.

Q. What is an outer panel?

A. An outer panel is the outmost panel on each side, and is described as the right upper outer, left upper outer, right lower outer, and left lower outer.

Q. What is meant by flight path?

A. The path of the center of gravity of an aircraft with reference to the earth.

Q. How many forces are there acting upon an airplane in flight?

A. There are four forces: (1) The weight of the machine acting vertically downward through its center of gravity. (2) The aerodynamic lift of the wings and other supporting surfaces acting through the center of pressure. (3) The total head resistance of the whole machine which acts in a direct parallel to the direction of motion of the machine through the center of resistance. (4) The propeller thrust acting through the center of thrust.

Q. Where should the center of pressure come on a well designed wing panel?

A. The center of pressure for the range of flying angle used should have a stable position, and, further, the range of movement along the chord should be a minimum. The center of pressure in a good wing section should lie between 0.3 and 0.45 of the chord distance from the leading edge at all incidences used in flying.

Q. Does the suction and pressure on a wing panel remain the same at all angles of incidence?

A. The combined loading remains at 100 per cent, but the greatest upper surface load or suction is when the angle of incidence is at zero, at which point the upper surface load would be 92 per cent and the lower surface load 8 per cent and the change between upper surface load and lower surface load will occur as follows, in accordance with the angle of incidence:

ANGLE OF INCIDENCE	UPPER SURFACE LOAD	LOWER SURFACE LOAD
	per cent	*per cent*
0	92	8
2	82	18
4	74	26
6	74	26
8	72	28
10	69	31

CHAPTER III

Description of Heavier-Than-Air Craft and Their Construction in General

Q. How many types of heavier-than-air craft are there?

A. There are four types: Land planes, seaplanes, flying boats and amphibious planes.

The following is a description of each:

A *land plane* has a body known as a fuselage to which one, two, or three pairs of wings are connected thereto. It has a structure called a chassis to which two or more wheels are connected with shock absorbers attached to the axles in order that the machine can land without damage and roll over the ground until its momentum or headway has expended itself. On the under side of the rear end of this fuselage is an ash or oak stick, known as a tail skid, which is covered with a metal strip which slides over the ground after the machine has landed. The fuselage referred to, if a single engine machine, has the engine located in the forward part of same, the gas tank in the rear of engine, one pilot seat in the rear of gas tank and another pilot seat in the rear of first seat, these being known as the front and rear cockpits.

A *seaplane* has a body known as a fuselage which carries engine, gas tank, two pilots, or pilot and observer, or pilot and student as the case may be, and has one or two pontoons connected thereto by the means of struts for landing and getting off the water. Seaplanes with only one pontoon usually have installed on the under side of the lower wings on the outermost ends what is known as a wing tip float. This prevents the wings from dipping in the water in getting off or making a turn on the water when a side gust may tend

to over-balance the machine somewhat, and the wing-tip floats, being hollow and buoyant offer a lift, thereby preventing wings from being submerged or struck by choppy seas. Seaplanes with twin pontoons do not have wing tip floats.

A *flying boat* consists of a light weight but strongly constructed covered over boat with a "V" shape bottom. Attached to this boat usually are two pair of wings, upper and lower, and in the hull of this boat is carried the gas and oil tanks, the pilot seats, which are usually two seats arranged side by side, gunner's cockpit forward or aft of the pilot's cockpit, as the case may be. The engine is supported by struts in a single engine machine overhead in this boat directly on the center line, or if twin engines, both being supported by struts between the lower and upper planes to the right and left of the hull respectively.

An *amphibious* plane is somewhat similar to a flying boat except it has a retractable chassis whereby it can be used in taking off on land and landing on water or vice versa. In other words, it can be used for both land and water purposes.

Q. How many wings are there on a heavier-than-air craft?

A. One set or pair of wings on a monoplane; two pairs of wings on a biplane; three pairs of wings on a triplane, and four pairs of wings on a quadruplane. Triplanes and quadruplanes are not used generally, the biplane and monoplane types being preferred.

Q. What is a rudder and how constructed?

A. A rudder is a vertical plane made of metal tubing, braced with spruce members and fabric covered, the upper portion being hinged to the vertical stabilizer and the lower portion to the fuselage or tail post of flying boat. The movement of rudder to right or left causes the machine to go in that direction, as the case may be.

Q. What is an elevator and how constructed?

A. An elevator is a horizontal plane placed in the rear of and hinged to the horizontal stabilizer. In most cases they are made in pairs either right or left elevator, and sometimes the spar on the leading edge is of one piece and the plane is built up with an opening in the center, in order that the rudder may turn to right and left. Whether there are one or two elevators, they both have the same movement, up and down together, in order that the machine may be caused to rise or glide, as the case may be. The elevation of the elevators causes the machine to rise and the depression of same causes the machine to glide downward.

Q. How is an N–9 fuselage constructed?

A. An N–9 fuselage is generally constructed of four ash members from the rear of the after cockpit forward, and from the rear of the after cockpit aft of spruce, being spliced together in this section These members are known as longerons, the forward ends of which are connected to a metal lightened flanged plate, known as a nose plate. The after ends of these members are secured to a vertical post of spruce that is known as a tail post. These four longerons are held apart vertically by spruce struts known as fuselage struts. In the wake of pontoon strut connection, the fuselage struts are of considerably larger sections than elsewhere. The upper and lower longerons are held apart by the means of transverse spruce braces, the whole being tied together by cross brace wires; between each section forward of the after cockpit by 19 strand galvanized wire, and aft of the rear cockpit by solid tinned wire, the reason for the difference in these wires being that the rear part of this fuselage is not subject to the same strains through shock and vibration that the forward and engine sections are. In the forward part of this fuselage there are two laminated longitudinal

pieces of wood known as engine bearers. The forward end of these bearers rest in the nose-plate previously mentioned. The rear ends of these bearers rest on a cross-brace and are secured by the means of "U" bolts. These bearers are usually of three laminations, the center being made of spruce, and the top and bottom laminations being made of ash. At the point in these bearers which bolt holes are bored to secure to engine base the bearers are copper flashed. This flashing is done by bending light copper around the bearer, which is tacked and secured with brass tacks with the heads soldered. Copper is not always applied, being often replaced by large washers under bolts. In the rear of the engine is the gas tank which is secured in place by the means of metal straps. In the rear of this, running fore and aft on each side, secured to the vertical braces, is what is known as the seat rail, the pilot seat being connected thereto, both forward and rear seats resting thereon, and connected to the lower longerons in the wake of both cockpits are floor board supports on which the floor boards in the cockpits rest. There is nothing installed in the remaining rear sections in the fuselage. The forward part of the machine, in the wake of engine and tank sections, are covered with sheet aluminum known as cowling, the sides and bottom of the remaining part of the fuselage being covered with fabric, grade "B", linen or cotton. Installed in the cockpits is a rudder bar for operating the rudder by the feet, also a control yoke for operating the elevators, and a control wheel mounted on the control yoke for operating the ailerons. On the top side, in the rear of the after cockpit is a light frame-work, fabric covered, known as streamlining.

Q. How is a wing panel constructed?

A. A wing panel is constructed of two main spars, usually of spruce, one known as the front spar and the other as the

rear spar. Along these spars are distributed a number of ribs, the inner end of wing panel having what is known as box ribs which consist of two ribs about a half an inch apart, not lightened. These are followed by what are known as former ribs, which are made of white pine, lightened by having elliptical and round holes cut in same. In the lighter type machines, in the wake of strut connections, and where the terminals for internal brace wiring is secured, there is one unlightened rib known as a compression rib. In larger types of machines this compression member is also made of round spruce, being tapered at the ends and swelled in the middle; also in some types of machines this compression member consists of a steel tube. Opposite, and placed intermediately between these former ribs on the forward side of the front spar is what is known as a nose rib. In the rear of the rear spar, and placed opposite the various main ribs, is what is known as the tail rib. The tail ribs are held in place, as well as the main, by the use of what is known as a cap strip. These cap strips are of spruce, and extend from midway of the top side of the front spar, across the rear beam, and over the top edge of the tail rib, and terminate at what is known as the trailing edge. On the under side of these ribs is a similar cap strip of spruce. These cap strips are ploughed out on one side for a depth of about $\frac{1}{8}$ inch, where they fit over the top and bottom edges of the ribs. They are secured to ribs by the use of glue, brass or galvanized nails, and screws. Between the lightened holes in all former ribs, the remaining wood is reinforced by the use of small pieces of birch veneer, which are glued thereto and secured with six brass tacks clinched.

The cap strips over the compression ribs are of a little wider dimension than those over the former ribs. Along the top of the front spar, on the forward edge, is secured a strip of the same thickness as the cap strips which is made

of spruce and is known as the filler strip. On the forward edge of the nose ribs there is secured to these ribs what is known as a nose moulding; this is hollowed out on one side to fit the leading edge of the nose ribs. Secured to this nose moulding, and extending back to the filler strip on the front spar, is a layer of three-ply veneer. On the outmost ends of the wing panels the spars are tapered down to a lesser dimension than at main body of the spar, it not being essential at this point for the spars to be of the same dimension as elsewhere, as a lesser load or strain is introduced at this point. Running from the leading edge and to the trailing edge around the end of this panel is what is known as an end bow, which is steamed and bent to the curvature required in the design; this is connected to the nose moulding and the metal trailing edge in a wing panel. The trailing edge of this panel is made of $\frac{3}{8}$ inch diameter steel tubing mashed slightly elliptical, having a copper strip brazed thereto in the wake of each trailing rib. These copper strips in turn are nailed to the top and bottom cap strips, thus forming the trailing edge of the wing panel. It is to be noted that intermediate panels do not have the end bow previously mentioned, but have box ribs on each end of the panel. A diagonal brace made of spruce is placed between the junction of the end bow and rear wing spar to stiffen the curvature at the outmost end. All wing panels are braced internally by the use of solid tinned wire running cross-wise between compression ribs. This makes the structure more rigid, and takes care of the drift load when machine is in flight.

Q. What are stringers?

A. Stringers, as used in aircraft construction, consist of longitudinal pieces of spruce or ash running parallel to the keel to which bottom planking is secured. Also, stringers are used in the bottom frame construction of pontoons and

those to which the curved deck is secured are known as deck stringers. Stringers are also used to stiffen the ribs in a wing panel being from $\frac{1}{2}$ to $\frac{5}{8}$ inch in diameter and run parallel to the front and rear spars, passing through the former and compression ribs near top and bottom in the center of panel, being secured at one end to the box ribs and to the end bow by means of small blocks, glue being applied to same where it passes through various ribs.

CHAPTER IV

Woods Used in the Construction of Aircraft, Their Defects, Method of Dry Kilning, Etc.

Q. What woods are used in the construction of airplanes?

A. The principal woods used in the construction of aircraft are spruce, ash, white pine, mahogany, Spanish cedar, basswood, Port Orford cedar, white cedar, birch, rock elm, white oak, and fir.

Maple is being used for forms. Rock elm, ash, and white oak are considered most practicable for sharp bends, but owing to the scarcity of rock elm and the added weight of white oak over that of ash, the ash is used almost exclusively where considerable strength is required. There are three kinds of mahogany; namely, Philippine, Cuban, and Honduras, the latter being considered best for aeroplane work on account of its closeness of grain, more flexibility, contains less defects, and is not as hard as the Cuban or Philippine mahogany.

Haskell veneer is used extensively in aircraft, and it is made in single, two, and three ply, or more if required. Fir sometimes may be substituted for spruce, but the objection thereto is the additional weight.

Basswood is considered the best wood for floors, although pine is being used; basswood and pine are interchangeable for keelsons.

Hickory can be used to advantage on such parts as foot controls, Deperdussin controls, and false keels where ash is now used. Also pontoons struts are being made of hickory and are considered better material for this purpose than any other wood.

Maple is an ideal wood for molds and patterns, it being very hard, close grained, and tough, and it will not warp and check like other woods.

Birch, other than that used in the manufacture of several ply veneer, is used singly as a stiffner on ribs in a wing panel between lightened holes, being glued and bradded thereto. Where birch is used in the manufacture of veneer, it is used for the outer plys and in the case of three-ply veneer the interior may be mahogany or poplar with the grain running at right angles to the grain in the outer ply. In some three ply veneer, the outer plys are made of mahogany and the interior of poplar.

It being a very difficult matter to describe the appearance of various woods so that a layman may understand same, a brief description of the various woods is given in order that one may have a slight knowledge of these woods and this may be of some assistance.

Mahogany is a hard wood and is of a reddish-brown in color and very close grained.

Birch is a close grained hardwood of a pale yellowish color.

Pine is a white soft wood, the cells being closely woven together.

Ash is a hard wood distinguishable by its long, straight, white grain.

White Oak is a hard wood of close straight grain, similar in appearance to white ash, except that it is darker in color and heavier.

Rock Elm is a hard wood similar in appearance to ash, but the fibers are somewhat closer and the wood is more tough.

Spanish Cedar is very light in weight and very soft. It has a very pale, reddish color. The grain is similar in appearance to mahogany, the grain being very close.

Basswood is very similar in appearance to white pine. It is somewhat stronger and a little heavier, and is very hard to detect from white pine after a coating of varnish is applied.

Port Orford Cedar and *White Cedar* are both practically the same in appearance, being of low specific gravity. They are both closely woven grain, not used to much extent at this time for aeroplane work.

Q. What are defects in wood?

A. Defects in wood consist of:

(a) Large and unsound knots
(b) Cross or diagonal grain
(c) Shakes
(d) Spiral grain
(e) Pitch pockets
(f) Dry rot and dote spots
(g) Wavy grain
(h) Worm holes
(i) Low density of wood as in spruce below 0.36 specific gravity
(j) Chipped grain
(k) Torn grain
(l) Brashness
(m) Case hardening
(n) Season checks
(o) Stained sap

NOTES

(a) *Knots:* Pin knots of about the size of a lead pencil are allowed, proportional to the width of piece. Edges must always be free of knots. The effect of knots depends upon their location with respect to the stresses to which the piece shall be subjected, as well as upon their size and character.

None but sound knots, firmly attached, should be permitted. Obviously, knots of any considerable size can not be allowed in any aeroplane parts because the parts themselves are comparatively small in cross sections. Since the weakening effect of knots results from their disturbance of normal arrangement of fibers, their seriousness can best be decided from a consideration of the grain.

(b) Certain defects may be allowed in conjunction with the use of *cross-grained material.* Between straight grain (1 in 25) and a slope not steeper than 1 in 20, $\frac{1}{4}$ inch knots are allowable when not nearer together than 10 inches. Where strength is so unimportant that a slope of 1 in 15 is permitted, even larger knots up to $\frac{1}{2}$ inch are harmless, provided they are not closer than 20 inches and do not affect the edge grain.

(c) *Shakes:* Shakes are sections in the wood fiber, either tangentially along the annual rings, or in a radial plane parallel to the axis of the wood fibers. They are the result of an actual rupture due to heavy winds, and sometimes caused by the felling of the tree. It requires a very minute inspection to locate this defect sometimes as the opening may not be visible, and again it may be only discolored. This defect can sometimes be determined by sounding the wood with a mallet, if there should be any question in the inspector's mind as to its soundness.

(d) *Spiral Grain:* Under normal conditions of wood growth, the axis of the principal wood cells or fibers are parallel to the axis of the tree, but frequently in spruce and other species the cells are inclined so that a line through the axis of a number of cells takes a spiral course. Spiral grain reduces the strength of wood considerably and a deviation from straight grain of more than 1 inch in 20 inches is sufficient for its rejection. Those familiar with spiral grain can detect it with the naked eye in rough green lumber by the direction

of the long shaggy fibers. The direction of the grain may be ascertained by picking at the fibers with a knife or splitting a small piece with a chisel. The most recently developed method and the surest used for detecting spiral grain is to place a few drops of ink either red, blue or green, on the tangential face and notice the direction which the capillary action draws the ink along the fiber.

(e) *Pitch Pockets:* Pitch pockets are openings between the annual rings which contain rosin either in liquefied, solidified, or granulated form. They are not as detrimental to the strength of a piece of material as ordinarily supposed, unless they are unusually large and accompanied by curly grain. The maximum length of a pitch pocket permitted is three inches and the maximum depth one-quarter inch. If pitch pockets are in the same annual rings they may not be closer together than 40 inches; in other portions of the section this distance may be 10 inches and 20 inches respectively.

The following is a table showing a combination of defects allowable with different slopes of grain:

ALLOWABLE SLOPE IN GRAIN NOT EXCEEDING	KNOTS		PITCH POCKETS	
	Maximum diameter permitted	Minimum distance between any two	Maximum length permitted	Maximum width or depth permitted
	inches	*inches*	*inches*	*inches*
1 inch in 25	$\frac{1}{4}$	10	$1\frac{1}{2}$	$\frac{1}{8}$
1 inch in 20	$\frac{3}{8}$	12	2	$\frac{1}{4}$
1 inch in 15	$\frac{1}{2}$	20	3	$\frac{1}{4}$

(f) *Dry Rot and Dote Spots:* Dote is an incipient form of decay in wood markedly affecting the strength of the pieces. Dote and dry rot usually are found at the heart center; it may be only a quarter of an inch or less in diameter, but upon cutting an end off the piece it may be an inch to several

inches in diameter. It is light, punk, brash and lifeless, and can be determined by weighing against a piece of known good material as it is very light in weight.

(g) *Wavy Grain:* Wavy grain are dips and curves in the annual rings; while this defect is not hard or difficult to see it is exceedingly hard to estimate the extent to which the piece is impaired. Where all of the annual rings are affected by the wave or dip, the deviation of 1 inch in 25 should govern rejections as in diagonal and cross grain.

(h) *Worm Holes:* Worm holes should be the cause for rejection of any material used in the construction of aircraft, because they impair the strength and the number and extent of same can not be predetermined or detected.

(i) *Low Density of Wood:* Low density of woods, as spruce below 0.36 can not be used. Wood of low density as spruce which has a specific gravity of less than 0.36 based on oven dry weight and oven dry volume must not be used for such aircraft parts as wing spars, struts, etc., where high strength is required. Where the moisture content of the wood is known, its density can be readily determined by its weight. Within a given species the density of the wood is governed by the proportion of summer wood cells in each annual growth ring; these summer wood cells have heavier walls and are easily distinguished by their darker color.

(j) *Chipped Grain:* This defect occurs in surface lumber when portions of the wood fiber are chipped out during machining, producing depressions in the surface of material. These chipped areas are often the result of poor manufacture and do not necessarily indicate irregularity of the grain and practically speaking, is only a minor defect.

(k) *Torn Grain:* Torn grain differs from chipped grain in that it usually occurs around knots or in portions of the surfaces where there are irregularities in the grain, such as waves and curls. Torn grain is always an indication of

unusual growth and usually signifies an inferior piece of wood, from the standpoint of strength.

(l) *Brashness:* Brashness is a form of decay found in ash and oak. It is a kind of dry rot; it is lighter in weight than a piece of wood of the same material in its normal condition, and should not be used any place where strength is required; when broken it will break sharp and snappish. It contains very little moisture and its specific gravity is way below the average. Brashness is sometimes caused by being piled for a long period of time.

(m) *Case Hardening:* Case hardening of lumber is brought about by too rapid drying, causing the surface to dry more rapidly than the moisture can pass to it from the interior. Case hardened lumber when resawed will invariably cup towards the inside if the interior of the lumber is too dry. Case hardening can practically be prevented by regulating the humidity so that the evaporation from the surface does not take place too rapidly. Case hardened wood is not permitted in the use of aircraft as its strength has been reduced.

(n) *Season Checks:* Season checks are small cracks here and there on a piece of material and their depth cannot be determined, therefore checked material is not permitted in aircraft. In order to prevent checking of material while being kiln dried, the ends of same are given a coat of asphaltum paint.

(o) *Stained Sap:* All stains and discolorations should be regarded with suspicion and carefully examined. It must be remembered that decay often spreads beyond the discoloration it causes, and that pieces adjacent to discolored area may already be infected. On the other hand, not all stains and discolorations are caused by decay of the wood. The blue sap stain of some hard woods and of many coniferous woods, including spruce, and the brown stain of sugar

pine are not caused by decay producing organism and do not weaken the wood.

It is to be noted that plywood is used to a great extent in the construction of aircraft and the following is a list of wood that may be used in plywood construction:

Basswood (Northern)	Redwood
Beech	Spanish cedar
Birch	Spruce
Cherry	Sycamore
Fir (grand, noble, or silver)	Western hemlock.
Mahogany (true and African)	White elm
Maple, (hard and soft)	White pine
Red gum	Yellow poplar

The veneer must be sound, clear, smooth, well manufactured stock of uniform thickness and free from injurious defects. Sap streaks and sound pin knots are not considered defects. Discolorations will be allowed. The veneer may be rotary cut, sliced or sawed.

Only certified glue or cement or certified casein or certified blood albumen which will meet the tests specified may be used.

The finished plywood should be dried to a moisture content of 9 to 11 per cent. Drying to excessively low moisture content induces excessive warping in panels.

A good test for the best grade plywood is to soak same in water for ten days or boiling same for eight hours. The following covers the tests required by the Department for plywood.

Shear Test: The strength of the glue joint shall be tested dry, wet after boiling in water for eight hours, and wet after soaking in water at room temperature for ten days. Fifteen test specimens shall be cut from a single panel, five for each of the three shear tests specified above. The ends of the specimen shall be gripped in the jaws of a tension-testing

machine and the load applied at a speed of less than $\frac{1}{2}$ inch per minute.

The shear values for grades A and B plywood must give average loads equal to those given in table below. The average load in a given case is the average of the five specimens cut from the panel. All specimens giving 100 per cent wood failures below the load specified below will be rejected in computing the average. All failures above the specified load and all showing partial or complete glue failures will be included in the average.

	GRADE A PLYWOOD		GRADE B PLYWOOD
	Cores $\frac{1}{16}$ inch or less thickness	Cores over $\frac{1}{16}$ inch thickness	
	lbs. per sq. inch	*lbs. per sq. inch*	*lbs. per sq. inch*
Tested dry..........................	325	300	225
Tested while wet after 10 days soaking in water at room temperature..	200	180	90
Tested while wet after 8 hours boiling in water........................	200	180	65

Q. What are the mechanical and physical properties of wood?

A. Wood differs from other structural materials in a great many ways, and the maximum efficiency in its use demands a thorough knowledge of the properties of wood and of the factors which influence those properties.

In some instances, specimens from different pieces of the same three have been found to show considerable difference in strength. In most cases, however, the wood of the highest specific gravity has the best mechanical properties regardless of its position in the tree. Where this is not the case, the toughest and most shock resistant material is found near the

butt. Above a height of 10 or 12 feet, variation of mechanical strength corresponds to the variation of specific gravity.

Among many of the hardwood species, material of very rapid growth is usually above the average in strength properties. Noticeable exceptions to this are found, however, and rapid growth is no assurance of excellence of material unless accompanied by a relatively high specific gravity. This is particularly true of ash. In the coniferous species, material of very rapid growth is very likely to be quite brash and below the average strength.

A piece of clear, sound, straight grain wood of any species is not necessarily a good stick of timber. To determine the quality of an individual stick by means of mechanical tests is extremely difficult, because the variation in strength of timber due to variation in moisture content, temperature, speed of test, et cetera, is so great.

A specific gravity determination is relatively simple to make, and it is probably a better criterion of all of the qualities of the piece than any single mechanical test which is likely to be applied; also the specific gravity determination need no adjustments such as would be necessary on account of the various conditions of a mechanical test.

When a piece of green or wet wood is dried, no change in mechanical properties takes place until the fiber saturation point is reached.

AIRPLANE SPRUCE

General Specifications

1. Airplane spruce shall be divided into the following grades and shall conform to the requirements specified:

I. Western spruce (Sitka) Picea sitchensis.

(a) Class A (wing beam stocks).

(b) Class B (long clears).

II. Eastern spruce (Picea canadensis, Picea rubbis).
(a) Class A stock.
(b) Class B stock.
(c) Class C stock.

General for Eastern and Western Spruce

2. (a) Airplane spruce shall be purchased as western or eastern spruce in accordance with the specifications given separately below for each kind.

(b) All lumber shall be straight grain, sawed fair and full to sizes given. Allowance will be made for ordinary shrinkage of partly seasoned lumber, but no lumber will be accepted which in the inspector's opinion will not finish when fully seasoned to the following dimensions:

GREEN (ROUGH SAWED)*		FINISHED (PLANED FOUR SIDES)*	
Thickness	Widths (inches)	Thickness (inches)	Widths (inches)
inches			
1 to 2.........	4 to $7\frac{1}{2}$ 8 to 12	$\frac{3}{4}$ to $1\frac{3}{4}$	$3\frac{5}{8}$ to 7 $7\frac{1}{4}$ to $11\frac{1}{4}$
$2\frac{1}{4}$ to 4........	4 to $7\frac{1}{2}$ 8 to 12	$1\frac{7}{8}$ to $3\frac{5}{8}$	$3\frac{5}{8}$ to 7 $7\frac{1}{4}$ to $11\frac{1}{4}$

* Bright sap is no defect.

All lumber to be manufactured from live and healthy trees. No material to be accepted which is cut from trees dead on the stump.

Dimensions

All dimensions shall be full.
Thickness shall be in increments of $\frac{1}{4}$ inch.
Widths shall be in increments of $\frac{1}{2}$ inch.
Lengths shall be in increments of $\frac{1}{2}$ foot.

3. Fractions of a foot are to be treated as follows:

Even half feet will be alternately counted out and allowed as a whole foot. Fractions under half foot will be dropped; fractions over a half foot will be allowed as a whole foot. Tapering lumber will be measured at one-third from the narrow end. Flitch-sawn lumber will be measured on the narrow face, under the bar at the middle of the length.

Inspections

4. Inspection to be at point of manufacture unless otherwise specified. The inspector shall have free access to all parts of the mills where this lumber is being manufactured, and shall be afforded every facility to satisfy himself that the lumber conforms to these specifications.

EASTERN SPRUCE

General

Class A. To be sound, straight-grained white or red spruce, either vertical or slash sawn, practically clear of all knots, a few scattering tight red or white pencil knots only being allowed, providing they do not injure the strength of the piece and are located as to allow for clear cuttings full length, 4 inches and up wide.

Red or black rot, wind shake, season checks, and cross grain at an angle of more than 1 inch in 20 inches, pitch pockets, glassy heart, or any other defect tending to injure the piece for the purpose intended will not be allowed.

Dimensions

Dimensions. To be 18 feet and up long, 4 inches and up wide; 2, $2\frac{1}{2}$, 3, $3\frac{1}{2}$ and 4 inches thick.

Class B. To conform to the general rules for Class A and to be 14 to 17 feet long, 4 inches and up wide. In general, this material shall run 2 inches, $2\frac{1}{2}$ inches, 3 inches, and 4 inches in thickness, but shall include pieces $1\frac{1}{4}$ inches and $1\frac{1}{2}$ inches thick of 14 feet and over in length.

Class C. To conform to the general rules for Class A and to be 8 feet to 13 feet long, 4 inches and up wide. In general, this material shall run $1\frac{1}{4}$ inches, $1\frac{1}{2}$ inches, 2 inches, $2\frac{1}{2}$ inches, 3 inches, $3\frac{1}{2}$ inches, and 4 inches in thickness, but shall include pieces of 1 inch in thickness irrespective of length over 8 feet.

WESTERN SPRUCE

General

To be sound straight-grained Sitka spruce material, practically clear four sides, either vertical or slash sawn. Bright sap, knots, or equivalent burls $\frac{1}{4}$ inch or less in diameter and narrow pitch pockets and bark seams $1\frac{1}{4}$ inches in length will not be considered defects. The general direction of the grain shall not deviate from the longitudinal axis of the piece at a greater angle than 1 in 20.

In pieces showing less than six growth rings per inch, rejection or acceptance shall be based on the specific gravity of the piece, which shall be not less than .36.

Class A. Wing Beam Stock. Size specifications to accompany order.

Class B. No. 1. Clears. Lumber of this grade to be 2 inches or more in thickness, 4 inches or more in width, and from 10 to 18 feet in length. Eighty-five per cent of this grade to be over 2 inches in thickness.

AIRPLANE ASH

Use

1. This specification covers the requirements for ash lumber for use in the construction of airplanes.

Materials

2. *Species.* The following species of ash may be supplied:

White ash	Fraxinus americana
Green ash	Fraxinus lanceolata
Blue ash	Fraxinus quadrangulata
Biltmore ash	Fraxinus biltmoreana

3. *Grades.* There shall be four grades of material as follows:

Grade A. To be 18 feet and over long, 6 inches or wider, 2 to 4 inches thick. Pieces 8 to 12 feet surface measure may have one sound, tight knot $1\frac{1}{4}$ inches in diameter or its equivalent. Pieces over 12 feet may have two such knots or the equivalent. The general direction of the grain shall not deviate from the longitudinal axis of the piece at a greater angle than 1 in 15.

Grade B. To conform to general rules for grade A and to be 14 to 17 feet long, 6 inches or wider, and $1\frac{1}{4}$ inches in thickness.

Grade C. To conform to general rules for grade A and to be 8 to 13 feet long, 6 inches or wider, and 1 to 4 inches in thickness.

Longeron stock: To be practically clear of all defects. Pieces 8 to 12 feet surface measure may have one sound, tight knot $\frac{5}{8}$ inch in diameter or its equivalent. Pieces 12 to 16 feet surface measure may have two such knots or the equivalent, and pieces having over 16 feet surface measure may have three or the equivalent. The general direction of the

grain shall not deviate from the longitudinal axis of the piece at a greater angle than 1 in 20.

Quality

4. All lumber shall be manufactured from live, healthy trees. No material to be accepted which is known as pumpkin ash or which is cut from swell butt and bottle neck portions of swamp-grown ash. Material shall be free from decay, worm holes, doty wood, unsound or loose knots.

5. *Defects.* Equivalent defects to be used in grading lumber.

NUMBER	SOUND AND TIGHT KNOTS	SOUND AND ENCASED KNOTS	THROUGH CHECK AND SPLIT	SURFACE CHECKS
	Average diameter	Average diameter	Length	Width and length
	inches	*inches*	*inches*	*inches*
1	$1\frac{1}{4}$	1	8	$\frac{1}{16}$ x 16
2	1	$\frac{5}{8}$	5	$\frac{1}{32}$ x 12
4	$\frac{5}{8}$	$\frac{3}{8}$	3	$\frac{1}{64}$ x 9
8	$\frac{3}{8}$	$\frac{1}{4}$	2	

Figures on horizontal lines represent equivalent, and the number of defects refer to the number of smaller defects that are equivalent to the larger ones of the same or different kinds.

Manufacture

6. *Measurement.* In the measurement of lumber of random widths, fractions of over $\frac{1}{2}$ foot, as shown on the board rule, must be counted into the next higher figure; fractions of exactly $\frac{1}{2}$ foot and less must be counted back to the next lower figure.

7. *Dimensions.* All lumber shall be sawed square edge and full to sizes given. Ninety per cent of the minimum widths mentioned in all grades of lumber must be full width, the

remaining 10 per cent may be $\frac{1}{4}$ inch scant in width. The following allowance will be made for finish in seasoned lumber:

GREEN (ROUGH SAWED.)	ALLOWANCE FOR FINISHING	
	S1S	S2S
	inches	*inches*
Thickness:		
$1\frac{1}{2}$ inches or under	$\frac{1}{8}$	$\frac{3}{16}$
$1\frac{3}{4}$ inches to 4 inches	$\frac{3}{16}$	$\frac{1}{4}$

8. *Tally.* A piece tally in feet must be made of all material. All lumber 1 inch or less in thickness shall be counted face measure. To obtain the board measure of lumber thicker than 1 inch the face measure must be multiplied by the thickness expressed in inches and fractions of inches.

9. *Stain.* Stain that will surface off in dressing to standard thickness will not be considered a defect.

10. *Wane.* In the grades A, B, and C, wane along the edge not exceeding one-sixth the length of the piece, or its equivalent at one end or both ends, not exceeding in thickness one-half the thickness of the piece and not exceeding $\frac{3}{4}$ inch in width in 1-inch to 2-inch lumber or 1 inch in width in $2\frac{1}{2}$-inch and thicker lumber, will not be considered a defect.

Inspection

11. All material shall, before acceptance, be inspected in accordance with the general specifications for inspection of material referred to in paragraph 1.

12. Inspection to be at point of manufacture unless otherwise specified. The inspector shall have free access to all parts of the mills where the lumber is being manufactured

and shall be afforded every facility to satisfy himself that the lumber conforms to this specification.

13. The inspector shall stamp each piece of accepted lumber with the official acceptance stamp.

Shipment

14. Rail shipments shall be made in closed cars, protected from the weather. The lumber must be carefully piled to avoid damage in transit.

WHITE PINE, SUGAR PINE, AND WESTERN WHITE PINE FOR AIRCRAFT CONSTRUCTION

General

1. White pine (Pinus strobus), sugar pine (Pinus lambertiana), and western white pine (Pinus monticola) used for aircraft construction shall be sound, free from wormholes, shake, rot, brashiness, loose knots, and injurious irregular grain.

2. Ten per cent of the pieces in a shipment may include a few scattered pin knots and pitch pockets not over 2 inches in length.

3. Bright sap will be allowed. Slight blue stain will not be considered a defect.

4. All lumber to be cut from live and healthy trees.

5. Limits for the slope of cross or spiral grain shall not exceed an angle of more than 1 in 20.

6. The minimum specific gravity of eastern white pine and sugar pine based on volume and weight when oven-dry shall be 0.36 and of western white pine 0.40.

Q. What is moisture content?

A. All green or partially dried wood contains a certain

percentage of moisture or water. A portion of this water is known as free water. The other water or moisture contained in woods is that retained in what is known as the hygroscopic cells and the fiber saturation point is known when the moisture content of a tested specimen shows 25 per cent. This is the point at which the moisture contained in the hygroscopic cells begins to evaporate.

Q. How much moisture content is there in green lumber?

A. Green lumber may contain from about one-third to two and one-half times its oven-dry weight of water. Expressed in percentage, there is from $33\frac{1}{3}$ to 250 percentage of moisture based on the oven dry weight.

Q. How many methods are there of drying lumber?

A. Two, one being known as air drying and the other as kiln drying, kiln drying being used almost exclusively for material to be used in aircraft construction.

Q. What is a dry kiln?

A. There are two kinds of dry kilns, one being stationary and the other portable. The stationary dry kiln usually consists of a brick or wooden enclosure, rectangular in shape, with steam radiators on one side and cold water radiators on the opposite side; also equipped for ejecting live steam in same in order to raise the humidity. Tracks are provided upon which trucks containing the material to be dried is properly spaced in order that the heated air can circulate through same. It is absolutely essential that the heat thrown off by the steam radiators should circulate and the cold water passing through the radiators on the opposite side of the enclosure draws the heated air towards it, therefore, setting up the necessary circulation. All dry kilns should contain several thermometers in addition to a com-

bined thermometer and hydrometer, both recording and nonrecording in order that the temperature and humidity may be known and governed throughout the charge.

A kiln known as the cutler dry-kiln was used extensively by various firms in kiln-drying aircraft material. This consists of a temporary frame work installed in various parts of a plant, being canvas covered, usually rectangular in section with steam radiators such as used in heating buildings, etc., with steam pipe running over the top of radiators parallel to same upon which several petcocks are installed in order to turn live steam in the enclosure to raise the humidity.

Opposite these radiators is a row of electric fans arranged to blow against the radiators at an angle of 45 degrees. This causes the heated air to strike the side of the enclosure, which is reflected backwards and passes over the charge of material in the kiln and returns by passing through the spaces between the material et cetera, thereby setting up the necessary circulation for even drying throughout.

Two steps are necessary in the drying of lumber: first, the evaporation of moisture from the surface, second, the passage of moisture from the interior to the surface. Heat hastens both of these processes. For quick drying, as high a temperature should be maintained in the kiln as the wood will endure without injury. Dry hot air will evaporate the moisture from the surface more rapidly than it can pass from the interior to the surface, thus producing uneven drying, with consequent damaging results. To prevent excessive evaporation, and at the same time keep the lumber heated through, the air circulating through the piles must not be too dry; that is, it must have a certain humidity.

Humidity is of prime importance, because the rate of drying and the prevention of checking and case hardening are directly dependent thereon. Only one species and approximately one thickness should constitute a kiln charge.

A difference not to exceed $\frac{1}{2}$ inch in thickness should be allowed.

The following is a brief description of the process of kiln drying from start to finish: First, a test should be made of the stock to be dried to determine the moisture content. This is done by weighing a few samples taken from the material and then placing samples in an electric oven and under a temperature of 212° F. until the material is bone-dry, when a difference in weight will determine the moisture content. Green wood as well as previously air dried wood after being placed in the kiln is steamed for a period of five to six hours for each inch of thickness and the humidity during this steaming period for either material must be either 100 per cent or not below 90 per cent in every portion of the pile.

The following table gives the range of temperatures and humidity throughout the period of drying:

State of drying	Drying conditions	
	Maximum temperature	Minimum relative humidity
	°F.	*per cent*
At the beginning	120	80
After fiber saturation is passed (25 per cent)	125	70
At 20 per cent moisture	128	60
At 15 per cent moisture	138	44
At 12 per cent moisture	142	38
At 8 per cent moisture	145	33
Final	145	33

It is to be noted that there are samples of this material placed in various parts of the pile in order that they can be readily removed so that the reduction in moisture content can be determined in order that the range temperature and humidity may be changed.

All aircraft material is dried down to a moisture content between 12 and 15 per cent, the idea being that the material should not contain more than 15 per cent moisture when placed in a machine. Material removed from a dry kiln before being tested should have from a week to ten days to adjust itself to shop temperature before being worked up.

It is to be noted that it takes anywhere from eight to fourteen days to kiln dry material, the length of time depending on the moisture content and the thickness of the material.

Great care is always to be taken when material reaches the fiber saturation point, which is usually when the samples show 25 per cent moisture content, that the material does not become case hardened, thereby ruining the material, as very slight case hardening only is permissible.

Before the material is removed from the kiln, in order to determine whether or not the material is case hardened, sections should be cut from the plank or timbers not nearer than two feet to the end of pieces. Samples shall then be sawed parallel to the wide face of the original board into tongues or prongs, leaving about one-half of the wood at one end of the section. If the prongs remain straight under a drying of twenty-four hours, perfect conditions of stress and moisture content are indicated. If the outer prongs bend in, conditions of case hardening are indicated.

It is to be noted that kiln drying or air drying of wood increases its strength, but engineers in designing, where large timbers are used, do not figure on this increased strength as they use material which contains checks, therefore, it is not the factor to be used in that type of design.

It is also to be noted that wood in drying does not decrease in cross section until the fiber saturation point is reached, which has been described in the foregoing.

Material used for the manufacture of the propellers is dried until the moisture content is only 7 per cent.

CHAPTER V

Propeller Manufacture, Splices, Struts, Wood Protective Coatings

Q. How is a propeller manufactured?

A. Propellers are manufactured from three different kinds of wood, namely, mahogany, oak, and walnut.

Laminations are sawn out from a template whose dimensions have been taken from the drawings. They are then given a surface drying in the kiln before being glued together, the laminations being marked to show how they should be glued. The temperature of the kiln, just previous to gluing the laminations for surfacing drying, should be 120° F., for thirty minutes to two hours with a humidity of 55°. They are then glued together, using certified hide or animal glue, and are to be kept in the clamps for 24 hours and after the removal of the clamps they should be allowed to set for an additional 24 hours, in the meantime being inspected for faulty joints, etc.

The glue used for this purpose should be heated to a temperature of 140° to 150° F., and is mixed with water at the ratio of two and one-half parts of water by weight to one part of glue by weight. Precautions should be taken that only a sufficient quantity should be mixed for one day's work. The brushes and pots used should be cleaned at the close of working hours. Keep glue pot cover on during heating of glue to avoid evaporation of water in glue. Keep forms clean and free of glue, the temperature of the room while laminations are in clamps at 90° F., and while out of the clamp at 80° F.

All laminations should be of vertical or quarter-sawed

grain or all flat grain if same is authorized, but vertical or quarter-sawed grain laminations should never be used together. In applying glue, laminations are coated on the upper side of one piece and the lower side of the other.

After laminations have been glued and inspected and found satisfactory, they are shaped either by machine or hand. The shaping of propeller blades by machine is usually done by an Ober lathe which uses a hardened master blade as a guide for roughing up. Where shaping is done by hand, draw knives and spoke shaves are used. In shaping out the propeller, a surface gauge is used, a protractor gauge graduating from one-tenth degrees, also a metal camber gauge. Propellers are balanced before the hub hole is enlarged for installation of hub bushing.

After propeller is balanced, the hole in the hub is enlarged, bushing pressed in with a neat fit, holes are bored and bolts pressed in two at a time by the use of an Arbor hand press.

Propellers are given a coat of filler, rubbed down and polished with rottenstone and oil. Two coats of varnish are used, both coats being well rubbed in.

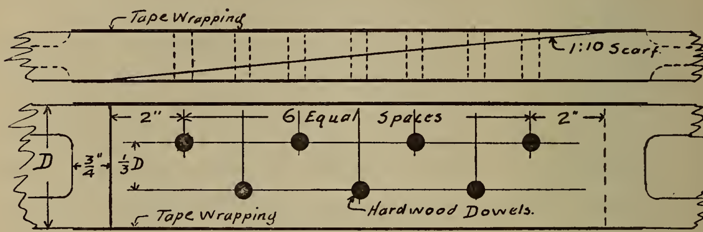
Tips of all propellers are coppered on the leading edge for about 18 inches and on the trailing edge for about 6 inches. The place to receive the copper is first shaved off to a depth the thickness of the copper; 14 ounce copper is used for this work. Copper is first cut out to a template, then riveted in place with copper rivets, then soldered over the head of rivets, then surplus solder removed and polished and drill three small holes in the end of copper to let any moisture that may accrue escape.

The propeller is balanced and, if not approved, a slight amount of material is removed in the vicinity of the hub in order to correct the balance.

Some propellers, instead of being copper tipped, are covered with linen and doped.

Q. Is it permissible to splice wing spars?

A. Yes. The length of the taper should be ten to one of the cross sections. See sketch with description below.



SOLID BEAM SPLICE.

Q. What stresses come upon wing spars, ribs, et cetera, when aeroplane is in flight?

A. The front spar is in tension and the rear spar is in compression, the ribs being in shear and bending.

Q. What stresses come upon interplane struts, or wing posts, as they are sometimes called, in a biplane?

A. These struts are always in compression, regardless of the position in which the aeroplane may be in at any time.

Q. Of what material are interplane struts made?

A. Struts are usually made of spruce, either from one solid piece or two or three laminations glued together with Casein glue, certified hide or animal glue. In large struts for heavy machines where three laminations may be used, the major portion of the center lamination may be hollowed out, except at the ends.

Some struts are made of metal tubes and stream lined with spruce or other light material, being wrapped and then doped.

Recent developments have shown that laminated struts that are wrapped with linen tape and doped do not stand up

well, as moisture gets in between the tape and wood causing the glue to soften and laminations come apart. Solid or laminated struts shall not be fabric covered.

The very latest method to keep out moisture on both propellers and struts where struts are built up of laminations—is to coat the surface with size, and then apply aluminum leaf which comes in booklet form, similar to gold leaf. After the application of aluminum leaf, and in order to make the surface uniform throughout, powdered aluminum is applied by the means of padded cotton.

It is to be noted that where any parts of aircraft material are to be spliced, such as longerons or wing beams, that just previous to applying the glue, a hot iron, usually an electric iron should be applied to the surfaces to be glued in order to remove any surface moisture.

WOOD PROTECTIVE COATINGS

The best protective coatings for wood parts used in aircraft construction is spar varnish.

The following table shows the resistance of wood to moisture, that has been given one or more coats of varnish.

Number of coats of spar varnish	Percentage of moisture excluded (based on untreated specimens)			Percentage of increase in width due to absorption of moisture		
	First varnish	Second varnish	Third varnish	First varnish	Second varnish	Third varnish
0	0.0	0.0	0.0	8.61	8.61	8.61
2	76.7	72.0	65.5	2.01	2.41	2.97
4	86.2	75.8	76.9	1.19	2.08	1.99
6	88.6	81.7	83.0	0.98	1.57	1.46
8	91.0	86.9	86.2	0.77	1.30	1.19
10	93.0	88.4	87.3	0.60	1.00	1.09
12	94.3	89.0	87.2	0.49	0.90	1.10

All flying boats are given two coats of varnish on the interior, except in the cockpits where an overflow of gasoline, or from other causes that gasoline may come in contact with the woodwork, this being given two coats of shellac which is not soluble by gasoline.

The side and top planking in H-S boats, being of only one thickness, is covered with fabric for water tightness. The planking is given a coat of marine glue. The fabric is then carefully placed on end caused to adhere firmly by being ironed with a hot iron. An electric iron is usually used for this purpose. This is followed by the application of one priming coat of naval gray enamel paint which has been thinned by adding one quart of turpentine to a gallon of the above paint. This is followed by two coats of the standard naval gray enamel. The exterior of bottom is given a coat of filler varnish, followed by two coats of naval gray enamel paint.

CHAPTER VI

Aircraft Wires and Their Uses

Q. How many kinds of wire are used in the construction of aircraft?

A. Four kinds, as follows:

(1) *Aircraft Wire,* is composed of one solid wire, tinned, and of round section.

(2) *Aircraft Strand*—non flexible—19 strand galvanized.

(3) *Aircraft Cable* or *Cord,* flexible galvanized 7 strands of 7 wires each.

(4) *Aircraft Cable* or *Cord,* extra flexible, tinned 7 strands of 19 wires each.

Q. Which is the strongest of the four wires when each are of the same diameter?

A. The breaking strength of the above wires are in the following order: Solid wire, strand wire, extra flexible, flexible, the solid wire being the strongest.

Tables 1, 2, 3 and 4 give complete information on the size, weight, and breaking strengths of the above mentioned wires.

Q. Where are the various wires mentioned used on aircraft?

A. Solid tinned wire is used for all diagonal and cross bracing of a fuselage of the N-9 type seaplane in bracing all sections of fuselage in the rear of the rear pilot's cockpit, for bracing control horns, on ailerons, elevators, rudders, all

Table 1

Tinned aircraft wire

American wire gauge	Diameter	Weight per 100 feet	Breaking strength	American wire gauge	Diameter	Weight per 100 feet	Breaking strength
	inches				*inches*		
0	0.325	28.16	15,000	11	0.091	2.20	1,620
1	0.289	22.27	12,500	12	0.081	1.744	1,300
2	0.258	17.75	10,400	13	0.072	1.383	1,040
3	0.229	13.97	8,300	14	0.064	1.097	830
4	0.204	11.10	6,700	15	0.057	0.870	660
5	0.182	8.84	5,500	16	0.051	0.690	540
6	0.162	7.01	4,500	17	0.045	0.547	425
7	0.144	5.56	3,700	18	0.040	0.434	340
8	0.128	4.40	3,000	19	0.036	0.344	280
9	0.114	3.50	2,500	20	0.032	0.273	225
10	0.102	2.77	2,000	21	0.028	0.216	175

Table 2

Galvanized non-flexible—19 strand

Diameter	Weight per 100 feet	Breaking strength
inches		
$0.312 = \frac{5}{16}$	20.65	12,500
$0.250 = \frac{1}{4}$	13.50	8,000
$0.218 = \frac{7}{32}$	10.00	6,100
$0.187 = \frac{3}{16}$	7.70	4,600
$0.156 = \frac{5}{32}$	5.50	3,200
$0.125 = \frac{1}{8}$	3.50	2,100
$0.109 = \frac{7}{64}$	2.60	1,600
$0.094 = \frac{3}{32}$	1.75	1,100
$0.780 = \frac{5}{64}$	1.21	780
$0.062 = \frac{1}{16}$	0.78	500
$0.031 = \frac{1}{32}$	0.30	185

TABLE 3

Galvanized-flexible—cable (7 strands of 7 wires each) 7 x 7

DIAMETER	WEIGHT PER 100 FEET	BREAKING STRENGTH
inches		
0.312 = $\frac{5}{16}$	16.70	9,200
0.250 = $\frac{1}{4}$	10.50	5,800
0.218 = $\frac{7}{32}$	8.30	4,600
0.187 = $\frac{3}{16}$	5.80	3,200
0.156 = $\frac{5}{32}$	4.67	2,600
0.125 = $\frac{1}{8}$	2.45	1,350
0.094 = $\frac{3}{32}$	1.45	920
0.078 = $\frac{5}{64}$	0.93	550
0.062 = $\frac{1}{16}$	0.81	485

TABLE 4

Tinned—extra flexible—cable (7 strands of 19 wires each) 7 x 19

DIAMETER	WEIGHT PER 100 FEET	BREAKING STRENGTH
inches		
0.375 = $\frac{3}{8}$	26.45	14,400
0.344 = $\frac{11}{32}$	22.53	12,500
0.312 = $\frac{5}{16}$	17.71	9,800
0.281 = $\frac{9}{32}$	14.56	8,000
0.250 = $\frac{1}{4}$	12.00	7,000
0.218 = $\frac{7}{32}$	9.50	5,600
0.187 = $\frac{3}{16}$	6.47	4,200
0.156 = $\frac{5}{32}$	4.44	2,800
0.125 = $\frac{1}{8}$	2.88	2,000

Note: If wires are galvanized instead of tinned the strengths will be about 10 per cent less.

internal wires of wings and non-skids, also for bracing wing tip floats on N-9 type seaplanes.

Strand wire is used to brace an N-9 fuselage forward of the rear cockpit and engine section, load and lift wires, pontoon float brace wires.

Flexible is not used to any great extent now, but when used it is for control wires where a certain amount of flexibility is required, *but not around pulleys.*

Extra flexible cable is used for control wires exclusively, and when used in conjunction with flexible cable—the extra flexible being always used around pulleys.

Q. In view of solid wire being stronger than the other wires of the same diameter, why is it not used elsewhere on aircraft?

A. The reason is, that excessive vibration causes solid wire to become fatigued, or crystallized, and it would soon break; such as is produced in the forward cockpits and engine section of a fuselage or load and lift wires, and on account of its stiffness could not be used for control purposes.

Q. On what wires are thimbles used in making up their terminals?

A. On all 19 strand, flexible and extra flexible wire.

Q. Are terminals in flexible and extra flexible and 19 strand wire on account of using thimbles made alike?

A. No. The terminals of flexible and extra flexible wires are made by splicing an eye around a thimble, the kind of splice being known as the navy terminal splice. 19 Strand wrapped described on page 100.

Q. How is the navy terminal splice made, and how is a terminal made in control wires?

A. This terminal is known as the navy splice terminal and shall be used exclusively on 7 by 19 extra flexible steel cable controls and 7 by 7 flexible steel cable. It may also be used for fiber and rope cord splicing.

Serving Cord: The serving cord shall be a seven-strand linen machine cord or an equivalent cotton cord, and after serving given a coat of shellac.

Cutting: Before the cable is cut it shall be thoroughly soldered for 2 or 3 inches to prevent any slipping of the wires after cutting. The flux used in this soldering shall be stearic acid rosin. Sal ammoniac or other compounds having a corrosive effect will not be permitted either as a flux or for cleaning the soldering tools. The cable shall be cut to the proper length by mechanical means only. The use of oxy-acetylene torches in any manner is not permitted.

Forming: The cable is bent securely around the proper size thimble and clamped, the tip of the thimble having previously been bent back to permit a tight splice. The length of the free end of the cable from point of thimble should be 2 to 3 inches longer than required to produce the number of tucks called for in table 1.

Splicing: After the cable is securely clamped in the thimble the strands are to be broken apart where soldered at the ends and separated back to the point of thimble. The number of tucks called for in the various sizes of cable is shown in the accompanying table 1.

A small wood, fiber, or copper mallet shall be used in pounding the splice. The anvil on which the splice is pounded shall be made of hardwood.

The process of making the splice is as follows: Take first free strand on right-hand side and tuck it under first strand which is nearest the point of the thimble on the right. Take free strand directly underneath the first strand and tuck it through the center of the cable. Three longitudinal strands should then lay each side of this tucked strand. Then insert the core wire directly over the same strand so that these two strands will come out in the same position. Then take the free strand on the extreme left and tuck it underneath the

strand which is nearest the point of the thimble on the left. Then take the free strand which runs parallel to the first free strand on the right side and tuck it under the longitudinal strand which is directly above the first longitudinal strand which had been tucked. Five strands should now have been tucked and two remain free. Then take the free strand on the left and tuck it toward the right underneath the remaining longitudinal strand. This free strand must come out directly above the second free strand which had been tucked. Then take the remaining free strand which is located on the right and tuck it toward the left underneath the same longitudinal strand. At this point a free strand will be between each longitudinal strand with the exception of the core wire which comes out with the center strand. The whole of the above is called the first tuck. At this point two free strands which cross directly above one another at the eye will be prominent. These strands should be pounded down to tighten the splice to the thimble.

For the second tuck, take the free strand on the opposite side of the splice which comes out to the right of the core strand and tuck it to the left over longitudinal strand and underneath the next longitudinal strand. This binds in the core strand to center of the splice. Repeat this operation with all the remaining free strands to the left. The tucks should now be again pounded down to make the splice tight and symmetrical. For the third tuck, take the strand which comes out to the right of the core strand and tuck it toward the left over the first longitudinal strand and under the next longitudinal strand. This operation will bind in the core strand. Repeat this operation with all the remaining free strands to the left. The core wire is then cut off close to the splice and the tucks are pounded as previously directed to tighten splice and to make it symmetrical. All free strands are now reduced one-third, but should not be cut until the

following complete tuck has been made by the six remaining two-thirds strands as heretofore directed for the full strand. This completes the fourth tuck. The free untucked one-third strands should now be cut off close to the splice. The splice is again pounded as previously directed. The free strands should now be halved and tucked to the left, allowing the remaining one-third strands to be free as previously indicated. The six remaining one-third strands are then cut off close to the splice. Cable one-fourth inch in diameter and larger should be spliced with six tucks in place of five to insure strength and proportion. In this case four complete tucks are made in place of three before starting to taper, as shown in table 1.

Serving: Place the end of the serving cord on the cable one-fourth inch above the fifth tuck. Carry the cord on the cable toward the thimble to a point midway between the thimble and the third tuck. From this point the cord should

TABLE 1

DIAMETER OF CABLE	7 BY 19 TINNED CABLE: Breaking strength	7 BY 19 TINNED CABLE: Proving load*	7 BY 7 GALVANIZED CABLE: Breaking strength	7 BY 7 GALVANIZED CABLE: Proving load*	NUMBER OF TUCKS: Full strand	NUMBER OF TUCKS: Two-thirds strand	NUMBER OF TUCKS: One-third strand
inches	*pounds*	*pounds*	*pounds*	*pounds*			
$\frac{3}{32}$	800	480	920	552	3	1	1
$\frac{1}{8}$	2,000	1,200	1,350	810	3	1	1
$\frac{5}{32}$	2,800	1,680	2,600	1,560	3	1	1
$\frac{3}{16}$	4,200	2,520	3,200	1,920	3	1	1
$\frac{7}{32}$	5,600	3,360	4,600	2,760	3	1	1
$\frac{1}{4}$	7,000	4,200	5,800	3,480	4	1	1
$\frac{9}{32}$	8,000	4,800	7,200	4,320	4	1	1
$\frac{5}{16}$	9,800	5,880	9,200	5,520	4	1	1
$\frac{11}{32}$	12,500	7,500			4	1	1
$\frac{3}{8}$	14,400	8,640	11,900	7,145	4	1	1

* Proving load is 60 per cent of the breaking strength.

then be tightly and closely served around the cable, covering all tucks to a distance on the unspliced portion equal to the diameter of the wire. The cord is then snubbed by inserting the end under four convolutions of the serving and the convolutions drawn tightly down on the cable. The serving is to be given two generous coats of shellac.

Proving: All tension and control cables shall be subjected to the proving load shown in table 1 under the heading "Proving." The load shall be applied gradually, taking approximately three seconds and maintained for a period of not less than one-half a minute. The proving load is estimated at 60 per cent of the breaking strength of the cable. The proving load takes out much of the stretch of the cable and splice and allows the total take-up of the turnbuckle to be more effective.

Q. How is a terminal made in 19 strand galvanized wire cable?

A. (1) Use a flux composed of stearic acid and rosin, stearic acid 25 to 50 percent, rosin 75 to 50 percent, using a warming glue pot to keep the flux in a fluid state.

(2) *Cutting.* Before cutting the cable the wires must be soldered or welded together to prevent slipping. The preferable process is to thoroughly tin and solder the cable for 2 or 3 inches by placing in a solder trough, finishing smooth with soldering tool. The cable may be cut diagonally to conform to the required taper finish.

(3) *Forming.* After soldering and cutting, the cable is securely bent around the proper size thimble and clamped, taking care that the cables lie close and flat and that the taper end for finish lies on the outside. If it is necessary to trim the taper at this point in the process, it is preferable that it be done by nipping, but grinding will be permitted provided a steel guard at least 3 inches long and $\frac{1}{32}$ inch thick

be placed between the taper end and the main cable during the operation and that the heat generated from the grinding does not melt the solder and loosen the wires.

(4) *Serving.* Serving may be done by hand or machine, but in either case each serving convolution must touch the adjoining one and be pulled tightly against the cable, with spaces for permitting a free flow of solder and inspection.

(5) *Soldering.* Care must be exercised to prevent drawing of the temper of any cable wires by excessive temperature or duration of applied heat. The flux used in this soldering shall be stearic acid and rosin as called for in paragraph (1). Sal ammoniac or other compounds having a corrosive effect will not be permitted either as a flux or for cleaning the soldering tools.

(6) Soldering is accomplished by immersing the terminal alternately in the flux and in the solder bath, repeating the operation until thoroughly tinning and filling with solder under the serving wire and thimble is obtained. The temperature of the solder bath and place where terminal is withdrawn shall not be above 450°F. A soldering iron may be used in the final operation to give a secure and good appearing terminal. Care must be taken that the solder completely fills the space under the serving wire and thimble. A slightly hollowed cast-iron block to support the splice during soldering may help in securing best results. Abrasive wheels or files for removing excess solder will not be permitted.

(7) As an alternative process of making terminals for non-flexible cable, the oxyacetylene cutting method and the presoldering method (soldering before wrapping) are permitted, but only on the following conditions: (1) That the process of cutting securely welds all wires together; (2) That the annealing of the cable does not extend more than one cable diameter from the end; (3) That no filing be permitted either before or after soldering; (4) For protection during the

operation of grinding the tapered end of the cable, a steel guard at least 3 inches in length and $\frac{1}{32}$ inch thick, shall be placed between the taper and the main cable; (5) The heat from grinding shall not draw the temper of the cable.

(8) *Proving.* All cable terminals shall be subjected to the proving load. The proving load shall be applied gradually, taking approximately three seconds and maintained for a period of not less than one-half minute. The means of applying the proving load shall be such that the specified load, for each size of cable, can not be exceeded through carelessness on the part of the workman. The proving load is estimated at 60 per cent of the breaking strength of the cable and takes out much of the stretch of the terminal, allowing the total take-up of the turnbuckle to be more effective.

(9) *Serving wire.* The serving or wrapping wire shall be of soft annealed steel wire thoroughly and smoothly tinned or galvanized, the diameter of the wire used for wrapping to be in accordance with the following table:

Table of Dimensions in Inches

Cable			Terminal dimensions			
Diameter of cable	Breaking strength	Proving load	L.	D.	C.	Serving wire B. & S. gauge
	pounds	*pounds*				
$\frac{1}{16}$	500	300	2	$\frac{9}{16}$	$\frac{1}{8}$	24
$\frac{3}{32}$	1,100	700	$2\frac{1}{2}$	$\frac{3}{4}$	$\frac{1}{8}$	24
$\frac{1}{8}$	2,100	1,200	$2\frac{7}{8}$	$\frac{7}{8}$	$\frac{1}{8}$	24
$\frac{5}{32}$	3,200	1,900	$3\frac{1}{4}$	1	$\frac{1}{8}$	24
$\frac{3}{16}$	4,600	2,800	$3\frac{5}{8}$	$1\frac{1}{8}$	$\frac{1}{8}$	20
$\frac{7}{32}$	6,100	3,600	4	$1\frac{1}{4}$	$\frac{1}{8}$	20
$\frac{1}{4}$	8,000	4,800	$4\frac{1}{2}$	$1\frac{3}{8}$	$\frac{3}{16}$	20
$\frac{5}{16}$	12,500	7,500	$5\frac{1}{4}$	$1\frac{5}{8}$	$\frac{3}{16}$	20
$\frac{3}{8}$	17,500	10,500	$6\frac{1}{4}$	$1\frac{15}{16}$	$\frac{1}{4}$	18
$\frac{7}{16}$	23,500	14,000	7	$2\frac{3}{16}$	$\frac{1}{4}$	18
$\frac{1}{2}$	28,500	17,000	8	$2\frac{1}{2}$	$\frac{1}{4}$	18

TERMINAL FOR SOLID WIRE, ROUND SECTION

The terminal loop is preferably formed in a bending machine, the ferrule being slipped over wire after loop is formed, and slipped tightly in position, the free end of wire then being bent snugly over the ferrule, the free end then being cut off so that it will cover from 3 to 5 turns of ferrule; the ferrule being made of 8 turns of wire of a similar gauge as the wire itself.

The soldering is accomplished by immersing the terminal alternately in stearic acid and rosin flux and solder bath, repeating the operation until tinning and filling under the ferrule is accomplished. If it is impractical to solder terminal by the bath process, the entire soldering may be done with a soldering iron. Abrasive wheels or files should never be used for removing excess solder. These wires should be subjected to proving load equal to 60 percent of its breaking strength in order to take out the stretch of the loop and allow the turnbuckle take-up to be more effective.

RIGID TERMINALS FOR STREAM LINE OR SWAGED WIRE

The terminals shall be machined preferably from heat-treated, cold drawn or cold rolled bars. If terminals are not made from the above, they must be heat treated after machining to give the necessary physical properties.

ROUND SWAGED WIRE STAY RODS

These wires are for use in aircraft where not exposed, such as inside of wings or fuselage, where greater strength is required than is obtained through the use of solid tinned wire of round section, and are adjustable to tension through right and left screw threads on ends or shanks of rods which may be in the form of an eye or fork which has a hollow shank

threaded to receive ends of rods. Are used principally on heavier type of aircraft.

In connection with wires and their uses, it is to be noted that sometimes either 19 strand wire or solid wire tinned is used for the rudder controls—H-16's have solid wire and H-S-l's 19 strand wire, but neither is ever used around pulleys.

CHAPTER VII

Turnbuckles

Q. What is a turnbuckle, and for what purpose is it used?

A. A turnbuckle as used in aircraft construction consists of three parts, one being known as the barrel, another as the fork, and the other as the eye, the barrel being bored out hollow and threaded with left hand threads in one end and right hand threads in the other; the forks and eyes are generally spoken of as turnbuckle shanks, one end of the fork or eye is threaded to screw into the barrel.

Turnbuckles are used to put a tension on the various wires used in the assembly of the various aircraft units, etc.

Q. Of what materials are the three parts composing a turnbuckle made?

A. The barrels are made of high strength brass, being machined to size from bars of brass, with a tensile strength per square inch of 67,000 pounds.

The shanks are made of nickel steel with a tensile strength of 125,000 pounds per square inch, being heat treated either before or after machining to refine the structure; these shanks are then zinc coated with a thickness of zinc approximately 0.001 inch thick.

Q. Are all turnbuckles of the same length that are used to tighten the same diameter wire?

A. No. There are two lengths of turnbuckles used on the same size diameter wires.

A short barrel turnbuckle is used on short wires and a long barrel turnbuckle is used on long wires, as there is not as much take-up in a short wire as there is in a long wire.

Q. How is the size of a turnbuckle determined?

A. The size of a turnbuckle is determined by the diameter of the shanks.

The following table gives complete information on turnbuckles.

NAVY NUMBER	LENGTH			TAKE UP	PIN HOLES IN		STRENGTH
	Threads	Barrel	Open C to C		Eye	Fork	
		inches	*inches*		*inches*	*inches*	*pounds*
8–SEF	6–40	2.25	4.5	1.25	$\frac{3}{16}$	$\frac{3}{16}$	800
16–SEF	10–32	2.25	4.5	1.04	$\frac{7}{32}$	$\frac{3}{16}$	1,600
16–LEF	10–32	4.00	8.0	2.79	$\frac{7}{32}$	$\frac{3}{16}$	1,600
21–SEF	12–28	2.25	4.5	1.00	$\frac{7}{32}$	$\frac{3}{16}$	2,100
21–LEF	12–28	4.00	8.0	2.75	$\frac{7}{32}$	$\frac{3}{16}$	2,100
32–SEF	$\frac{1}{4}$–28	2.25	4.5	0.61	$\frac{9}{32}$	$\frac{1}{4}$	3,200
32–LEF	$\frac{1}{4}$–28	4.00	8.0	2.36	$\frac{9}{32}$	$\frac{1}{4}$	3,200
46–SEF	$\frac{5}{16}$–24	2.25	4.5	0.60	$\frac{5}{16}$	$\frac{5}{16}$	4,600
46–LEF	$\frac{5}{16}$–24	4.00	8.0	2.35	$\frac{5}{16}$	$\frac{5}{16}$	4,600
61–LEF	$\frac{3}{8}$–24	4.00	8.0	2.08	$\frac{11}{32}$	$\frac{3}{8}$	6,100
80–LEF	$\frac{3}{8}$–24	4.00	8.0	1.81	$\frac{3}{8}$	$\frac{3}{8}$	8,000
125–LEF	$\frac{7}{16}$–20	4.25	9.0	2.06	$\frac{16}{32}$	$\frac{7}{16}$	12,500
175–LEF	$\frac{1}{2}$–20	4.25	9.5	2.06	$\frac{9}{16}$	$\frac{1}{2}$	17,500

Note: In column headed "Navy Number," the letters indicate the type of turnbuckle: S—Short, L—Long, E—Eye, F—Fork. Thus SEF indicates a turnbuckle having a short barrel, with one eye end and one fork end.

The following is a table giving size, etc., of shackles used in connecting up wires in aircraft construction. It is to be noted that a turnbuckle contains three parts, previously described, but in very large turnbuckles the fork is omitted and another eye screwed into turnbuckle barrel. Where this is done, the turnbuckle consists of two eyes and barrel, the connection being made to the fitting by means of shackle being passed through eye of turnbuckle and then secured to

fitting by a clevis pin; such clevis pins being secured by cotter or split pins as they are sometimes called.

Shackles

NUMBER	DIAMETER OF WIRE	DIAMETER OF PIN HOLE	BETWEEN JAWS	DIAMETER OF LOOP	CENTER OF EYE TO CENTER OF LOOP	STRENGTH SHACKLE AND CABLE
						pounds
8	0.172	0.188	0.109	0.250	0.563	800
16	0.172	0.188	0.156	0.250	0.563	1,600
21	0.172	0.188	0.156	0.250	0.563	2,100
32	0.250	0.250	0.203	0.375	0.750	3,200
46	0.281	0.313	0.203	0.438	0.813	4,600
61	0.313	0.375	0.203	0.500	0.875	6,100

Clevis pins

Note: The pins used with shackles, turnbuckles, stay-wire fittings and other airplane parts requiring ready assembly are called "Clevis pins" in these specifications.

Those used with shackles and turnbuckles are supposed to be 0.002 inch less in diameter than the pin hole.

The following defects are frequently found in turnbuckles upon inspection at manufacturers:

Barrels drilled eccentric with outside diameter.

Mutilated shanks, deep tool marks, warped or bent steel shanks caused by rough handling or heat treatment.

Cracked barrels, developed in machining.

Shanks should screw into barrel with a snug true fit, and capable of being turned by hand to within $\frac{1}{8}$ inch of fillet. Assembled turnbuckles should not show any appreciable side shake when three threads on shank are exposed.

CHAPTER VIII

Aircraft Fittings

MANUFACTURE, WELDING, BRAZING

Q. Of what material are aircraft fittings made?

A. Aircraft fittings are made of both nickel steel and mild steel, except pulleys, which are made of high strength brass, Tobin bronze, or canvas bakelite.

Q. How many methods are there used in making metal fittings?

A. Four methods, as follows: Drop forging, stamping machines, by the use of chopping machines for cutting to shape and bending and finishing by hand, and castings used occasionally. Some fittings are cast, such as rudder bar supports, pontoon step castings, etc.

Q. Name some fittings that are made by the above mentioned processes?

A. Turnbuckle shanks, sockets, brace ends, upper and under side wing plates, shackles, the lug end of a strut fitting; pontoon fittings are drop forged, the strut fittings in most cases and pontoon fittings in all cases having an additional part welded thereto to complete same. Numerous fuselage fittings and hinge parts are stamped out, and parts built up by welding or brazing together. Miscellaneous parts that it is not practical to manufacture by the above two methods are outlined on a sheet of steel by the means of scribe or light center punch marks and then chopped out to shape by a chopping machine which cuts about $\frac{1}{4}$ inch of metal along the

desired line at each stroke and operates very rapidly in an up and down motion. The nose plates for fuselage type machines are made as follows: Nearly all nose plates are made up of two pieces riveted together, being first outlined on sheet of steel from which to be made, then chopped out on outline, followed by chopping out lightened holes, then plates are annealed, then flanged (for stiffness) by placing same between two metal forms and hammering flanges around edges and lightened holes, drill holes for the two parts that require riveting together, then rivet, sand blast to clean same, zinc coat and black enamel for rust proofing.

Q. Why are fittings annealed?
A. Annealing softens the metal, and relieves internal strains or any crystalization that has taken effect.

Q. What does annealing consist of?
A. The process consists of heating the metal to a temperature above the critical range, 50 to 200°F., or approximately 1650°F., and allowing same to cool slowly through the critical range, sometimes being left in the furnace with the heat turned off, or placed on warm sheets of steel away from dampness or cold drafts.

Q. What is meant by heat treatment of metals, and what are its effects on same?
A. The heat treatment of aircraft parts consists of placing parts to be heat treated in a furnace, which may be either heated by coal, oil, gas, or electricity, at the present time the oil furnace being preferred. Attached to this furnace is an electric Pyrometer which shows the temperature on a gauge located several feet away from the furnace, the critical range being 1600° F., to which the fittings are heated, then removed from furnace and quenched in a trough of crude oil. Replace

fittings in furnace, reheat to 1100° F., and place same on floor (either metal or dry ground) away from cold drafts and dampness; this partially draws the temper, thus refining the structure of the metal and relieving any internal strains. The degrees in temperature as given above are not used always; the latter may be as low as 600° F., depending on the degree of hardness desired.

Q. How are steel or other metals tested for their physical properties?

A. The testing of metals consists of pulling same apart in a test machine designed for the purpose, and while being pulled apart, the following physical properties are determined: Elastic limit, elongation, ultimate strength, and yield point. The procedure is as follows: A sample of the metal is machined to a predetermined diameter for eight (8) inches in length, then the ends of the original size are secured in the jaws of the test machine and the machine started. To determine the elongation it is necessary to place two prick punch marks on the test piece four (4) diameters apart of the piece being tested; the change in length divided by original length is the percent of elongation. Elongation is usually expressed in percentage of 2 inches.

The elastic limit of a piece of metal is the maximum strain it will withstand without producing a permanent set.

The yield point takes place after a test piece of material has reached its elastic limit.

Ultimate strength occurs after the metal begins to yield, the maximum number of pounds stress per square inch equals load in pounds as read on the beam divided by areas of cross section.

Reduction of area is determined by measuring area before and after elongation.

Q. How are metals analyzed to determine their composition?

A. Shavings or turnings from a sample are given a chemical analysis in order to determine its component parts. and from this analysis the quantities of such impurities as sulphur, slag, silicon, etc., are determined.

Q. What does a microscopic examination show?

A. The microscope shows the fine or coarse texture, fibers, etc. Photographs are also made of the machined end of a sample piece: these will show the defective component parts plainly.

Q. How are steels welded?

A. In welding steels no flux is used. The oxygen acetylene flame is applied, using a small rod of Swedish iron to fill in; care must be taken not to burn the iron; welded parts are annealed to relieve the local strains.

Q. What defects may be expected?

A. Too much metal, poor workmanship, non-adherence of parts welded, also welded out of true position.

Q. What defects may be expected in drop forgings?

A. Laps and cold sheets, splits, cracks, burned metal, defects at bends, undersize, and improperly drilled holes as to size and alignment.

Q. What defects may be expected in stamped or handmade fittings?

A. The principal defects are cracks in bends, oversize holes, and non-alignment.

Q. What is spot welding?

A. Spot welding in aircraft work consists of electric welding in small spots to hold two parts together so they may be brazed or welded together. The operation consists of placing the two parts to be tacked together between two electrodes allowing a high current to pass through them. Spot welding is not depended upon for strength on account of its uncertainty. Superficial inspection will not determine whether it is a good weld or not, and it would have to be torn apart to determine its strength. However, it is a good method of securing two parts together to be held in position for a further operation.

Q. How many methods are there for brazing?

A. Three—open fire, pot brazing, and torch.

Open fire brazing consists of an iron stand with fire brick placed on top. Two torches are placed at angles of about 45 degrees; the torches burn oil or gas and operate under about 8 pounds pressure. At the bottom of the brick enclosure is a recessed brick which contains the molten flux (borax); a graphite coating is applied to the metal in the vicinity of that part to be brazed to prevent brazing material from adhering, except where desired. First heat metal to a cherry red, care being taken not to burn, then baste part to be brazed with the molten flux and apply brazing wire to parts to be joined together; as soon as wire touches it melts and flows in the joints. Turn the tube or fitting as the case may be, and when all joints are filled, remove same, and place on floor to cool.

Pot brazing is an identical arrangement as previously described. The flame from the two torches is applied against a pot of spelter to which a small per cent of borax has been added; the parts to be brazed are immersed in the molten metal, a graphite coating being applied in the vicinity of

part to be brazed to prevent adherence of surplus metal. Torch brazing consists of heating the parts to be brazed together by means of an oxygen acetylene torch and a wire of spelter. This method has been discontinued on account of the intense flame frequently burning the metal. In connection with brazing and welding the following is to be noted: Laminated fittings of metal normally under stress, which are brazed or welded, shall in addition be thoroughly riveted, or otherwise secured in a satisfactory manner. Brazed or welded joints shall not be depended upon to transmit high tensile stresses. Welding or brazing shall be restricted to parts not otherwise possible of fabrication, and only in approved locations.

BRAZED JOINTS

Steel best suited for brazing should be of low carbon, preferably not higher than 0.50 per cent; sulphur (maximum), 0.15 per cent; manganese (maximum), 0.90 per cent; phosphorus (maximum), 0.10 per cent. Alloy steels are also suitable for brazing, providing the above limits of carbon, sulphur, phosphorus, and manganese are not exceeded.

Any parts requiring a bend of more than 45 degrees over a diameter equal to or less than the thickness of the plate shall be normalized before bending, and if the part is highly strained it shall be made from a steel whose upper critical range does not exceed 1580° F., and shall be heat treated. Heat treating improves the brazed joint as well as the steel. If the design of a fitting to be brazed is such as to permit the use of a steel which has ample strength in its normalized condition and does not require heat treatment, the upper critical temperature range of the steel is immaterial.

Flux. Stearine, borax, or, preferably, boracic acid may be used. Ammonium chloride, zinc chloride, or similar

salts having corrosive properties or acids, shall not be used in the flux.

Brazing wire. Brazing wire will be used having the following chemical contents:

	per cent
Copper	68 to 72
Lead (maximum)	0.30
Iron (maximum)	0.10
Total impurities (maximum)	1.25
Zinc	Remainder

The melting point of the brazing wire varies from 1650° to 1760° F., and begins to appreciably lose its strength at 1600° F.

Cleaning. All parts to be brazed shall be thoroughly cleaned by sand-blasting, or with emery cloth, to remove all oxide and grease. No filing or abrasive wheels will be permitted. The parts should be reasonably well fitted and secured in position by clamps or spot welding. Treatment with weak hydrofluoric acid of 5 to 10 per cent strength for a very short period (one-half minute) may follow the sand-blasting in order to remove any small particles of sand, so that the brazing process will be successful. Hydrofluoric acid is the only acid that will be permitted for this purpose. The parts treated shall immediately be cleansed to remove all acid. This may be accomplished by dipping into weak soda solution (8 pounds sal soda, or 4 pounds of soda ash, and 25 gallons of water) and then rinsing thoroughly with hot water.

Heating. Care must be exercised in heating the parts to be brazed that the metal on both sides be sufficiently heated to relieve strains.

The brazing flame shall be neutral (neither oxidizing nor reducing), but may vary on the oxidizing side (blue flame); but must not vary on the reducing side (yellow flame).

The steel must not be overheated. A temperature of 1770° to 1800° F. (light yellow) should not be passed.

Application of Brazing Metal. Care must be used to see that the flux and brazing wire are properly applied so that the metal will flow into all crevices of the joint without excess on the surface, as no filing or abrasive wheels will be permitted either before or after the joint is brazed.

HEAT TREATMENT OF BRAZED JOINTS

The objects of the heat treatment of brazed joints are:

(1) To remove internal stresses caused by brazing.

(2) To restore ductility and toughness impaired by overheating.

(3) To enhance all the desirable physical properties as much as possible for each particular purpose. Brazed joints to be heat treated shall not be under a strain which would cause the part to warp or become misplaced upon heating, as the furnace temperature rises too near the softening point of the brazing metal. Consequently any shifting of the parts would cause distortion. It is therefore necessary that all joints should have been previously spot welded, folded, or riveted in an approved manner.

The parts shall be heated in a muffle or refractory furnace to a temperature sufficiently above the upper critical temperature to insure quenching at a temperature slightly above this point. The time the piece should be held at this temperature in the furnace depends upon the size of the piece. This time, however, need not be longer than required to give a uniform temperature to the part. Quench in oil and reheat to such a temperature as will give the required physical properties. (This temperature may be obtained by trial or from the steel maker.) Withdraw from furnace and cool in air.

It is to be noted that all temperatures shall be ascertained

by the use of pyrometers, and the pyrometers shall be frequently checked to insure accuracy.

Q. How should a good piece of steel appear that has been tested in a test machine?

A. A piece of good material should show a close fibrous light grey texture, free from crystallization, slag, and other defects.

Q. What is meant by shear test?

A. A shear test consists of inserting a piece of metal that has been machined to size through a block that has a hole through same with center of block removed on one side, a detachable piece that will fit in the above mentioned slot, that also has a hole through same; the piece of metal to be tested also passes through the hole in this detachable piece, a load is applied on top of this detachable piece by a test machine until test piece has been sheared. The character of a good piece of material should show a clean cut or shear as the term applies, no torn fibers or ragged ends.

Q. What is the torsion test?

A. The torsion test consists of placing test piece in the jaws of a test machine, one head of same being held stationary and the other movable; turn movable head until metal breaks, the twisting moment is registered by a scale beam, and the angle through which the piece is twisted is read from a scale near the movable head. The nature of failure in ductile material would show that fibers had twisted almost throughout its entire length. The nature of failure ordinarily, the break occurs in a plane almost at right angles to the axis of the bar, the end near the fixed head twists little and that near the movable head twists considerably; this test sets up shearing stresses in the bar.

Q. What is a compression test?

A. The compression test consists of placing a piece of material 1 inch in diameter and 2 inches in length, stood on end on the test machine cap and load applied. The nature of failure of ductile material shows cracks around its radial surface after cross section has about doubled by compression; brittle materials, as hard steels, usually fail by shearing off diagonally, the fracture occurring at the maximum strength of the piece, there being little or no compression of the piece.

Q. What is modulus of rupture?

A. Modulus of rupture is sometimes defined as the intensity of stress at the instant of rupture upon a unit of section which is most remote from the neutral axis on the side which first ruptures; it is usually determined by L., inches B., and D., each 1 inch; it follows that the modulus of rupture is 18 times the load required to break a bar 1 inch square, supported at two points 1 foot apart, the load being applied in the middle.

Q. What is an impact test?

A. The impact tests consist of dropping a casting from a specified height, or striking same with sledge hammer blows, a pendulum with weight allowed to swing through a certain arc and striking test piece; the value of this test determines the soundness of the material, by the tone of sound imparted.

Q. What is the fatigue test?

A. The fatigue test consists of repeated applying and releasing load. A special design machine is used for this purpose. The nature of failure is similar if load is applied suddenly. It begins by forming crystals with each cycle, which eventually work their way into the interior of the metal, until metal finally breaks.

Q. What effect do the various alloying elements and impurities have on steel?

A. Sulphur forms sulphides with iron and manganese; iron sulphide makes steel "hot short." Phosphorus forms iron phosphide, which is in solution with the steel and causes steel to be "cold short;" this causes rapid crystal growth while steel is heated through critical range, making refinement of grain very difficult or impossible. Silicon forms silicide with iron, which forms solid solution; it has no appreciable effect on structure of physical properties of steel. Manganese forms manganese sulphide, making sulphur less injurious, and helps to harden steels; if manganese exceeds 90 percent, there is danger of injury in quenching manganese steel. Nickel forms solution and lowers critical range, increases hardness, toughness and tensile strength with only a slight decrease in ductility; retards rate of change of structure in cooling through critical range. Chromium forms solution imparting great hardness; retards rate of change of structure in cooling through critical range. Vanadium acts as a cleanser, removing dissolved gases; gives a very good combination of strength and toughness; is apt to cause segregation.

Q. What does hardening of steel consist of?

A. Hardening of steel consists of heating the steel above the critical range, and quickly cooling it through the critical range in some medium such as oil, water, or brine.

Q. What is meant by critical range as applied to heating steel?

A. The critical range means the number of degrees Fahrenheit used for steel when heating same without endangering the structure, namely, 1600° F., to toughen and temper steel, called heat treating. This consists of heating

to 1600° F., quench in oil, reheat to 1100° F., and lay on the floor to cool; this latter is called drawing the temper; when a specified degree of hardness is desired, the number of degrees to which metal will be heated before drawing the temper will vary, depending upon the degree of hardness required.

Q. How is metal tested for hardness?

A. There are two methods, both being used in testing the hardness of aircraft fittings, one being knownas the Brinell method, which consists of placing fitting or sample to be tested in a Brinell testing machine, then apply 3000 kilograms load, which is done by hand screw power on the smaller type machine. A vertical shaft contains a hardened steel ball at its lower extremity (the shaft being tapered at this end), which makes an impression in the test piece when load is applied, the amount of load being shown on a glass covered dial on top of machine. The greater the diameter of the impression made in metal under test, the softer the material; the smaller the diameter of the impression, the harder the metal. The indentation is measured and referred to a table to determine its hardness.

The other method is known as the scleroscope method, which consists of a graduated glass containing a small steel ball. Attached to this tube is a rubber bulb, which when pressed, causes the steel ball to rise in the tube to an exact height from which it falls on test piece placed at lower extremity of vertical tube; the ball rebounds when it strikes the metal, and the higher it rebounds the harder the metal. The height to which it should rebound for the class of material being tested is known by reference to table of hardness corresponding to graduations on glass tube. This is the most rapid method known for this kind of test.

AIRCRAFT HEXAGON HEAD BOLTS

Aircraft bolts are made from heat-treated, cold drawn or cold-rolled bars, which have been heat-treated previous to machining. If not made from heat-treated, cold-drawn or cold-rolled bars, they must be heat-treated after machining to give metal the necessary physical properties. The above is not intended for engine construction.

AIRCRAFT HEXAGON NUTS

For bodies and wings (not engines)

Q. How many kinds of aircraft nuts are there?

A. Six kinds, as follows: Plain hexagon, plain thin hexagon, plain slotted hexagon, plain ball hexagon, castle hexagon, castle ball hexagon. They are manufactured from cold-drawn or cold-rolled steel or hot-rolled steel; the material used shall have a tensile strength of 70,000 pounds per square inch, and nuts must not be hardened or tempered after machining. All bolts and nuts shall be zinc coated, as described elsewhere under rust-proofing, and after coating permit turning with fingers on bolt without excessive shake; nuts and bolts of the same dimension should be interchangeable.

AIRCRAFT WASHERS

There are several kinds of washers used in the assembly of aircraft, namely: Bevel washers, both round and square, as well as the flat round washer. These are manufactured from cold-rolled or cold-drawn steel, cyanide hardened and zinc coated. All washers should be clean cut with both faces free of burrs or nicks. There is also a spring steel lock washer which prevents nut from backing off, and where used, the bolt end is not drilled and cottered such as is done in the case of the other washers where castellated nuts are used.

CHAPTER IX

Sand Blasting and Pickling

Q. How are fittings cleaned?

A. Practically all steel aircraft fittings (except threaded bolts or parts that may be injured, or very small parts) are cleaned by the sand blast process which is as follows: Sand blasting of large parts consists of placing same in a furnace like enclosure, which has a funnel shaped sand container about six feet above the enclosure, the sand flowing downward through a pipe by gravity, connected to this sand pipe at the point where it enters the enclosure is an air hose and by this means the sand is blown against the metal parts to be cleaned, thus removing the oxide, etc., the cleaned fittings present a light grey color. The enclosure has a door in which is installed a peep window of mica or celluloid, also a small round aperture for a man's arm, these two latter are for the purpose of cleaning irregular shaped fittings that would require repeated opening and closing the large door to turn fittings, therefore, irregular fittings are cleaned by being held in the hand through the aperture mentioned and turned while being cleaned. This necessitates the operator wearing a long sleeve rubber glove for protection. The air pressure for this operation may vary anywhere from 60 to 90 pounds, but usually about 90 pounds.

Q. How are small fittings sand blasted?

A. All miscellaneous small parts (not threaded) are cleaned by the sand blast tumbling method. This consists of a perforated barrel like enclosure, which is hexagon shaped in cross section which revolves on a horizontal shaft in

another box like enclosure, the sand being supplied by gravity from an overhead container having an air hose or pipe connected to sand pipe, the sand being ejected into the revolving drum under a pressure of about 60 pounds, thus cleaning the fittings.

Q. How are parts not sand blasted cleaned?

A. Threaded metal parts and others that might be injured by the sand blast process are cleaned by the pickling process, which consists of what is known as the potash bath, using one and a-half pounds of potash to every two gallons of water. This solution is kept hot and an electric current is sometimes run through this solution while dipping of fittings is in progress. Fittings are usually secured to a wire, several in number, in order to expedite and facilitate handling. It only takes about 15 seconds to remove the grease and scale.

There is also an acid and water solution that could be used, and is used in many instances for cleaning metal parts other than aircraft fittings. This latter method, however, is forbidden on aircraft parts as it is injurious to the metal.

Q. How are fittings rust proofed?

A. After cleaning, as described above, fittings are zinc coated by hot dipping or zinc plating (electro galvanizing) provided that hot dipping shall not be used on such alloy or heat-treated steels as will be injuriously affected at the temperatures employed. For such steels the cold zinc plating process should be used. Samples should show no iron rust after 100 hours continuous exposure at room temperature to a salt spray of 20 per cent salt (sodium chloride) solution. The average thickness of zinc coatings on accurately dimensioned parts, screw threads, etc., should not exceed .002 inch in thickness, but may be of greater thickness on other parts.

It is to be noted that the copper and nickel plating of fittings have been abandoned, and zinc coating, where coatings are used, is recognized as the best protection against corrosion known at this time. Tin, copper, and nickel plating coatings, are all more or less porous and do not offer the same protection as zinc.

Note: Fittings that start to corrode, after being in service, should be cleaned and given a coat of red lead paint, and after paint is thoroughly dry give same either a coat of black enamel or naval gray enamel paint.

CHAPTER X

Steel and Copper Tubes

Steel tubes for highly stressed parts such as engine braces and interplane struts shall be of medium carbon steel seamless tubes, cold-drawn, annealed after drawing; the tubes are then heat treated and quenched in oil.

Welded steel tubes are suitable for only such parts not subjected to compressive stress or to high tension. These tubes are annealed after welding.

A good tube whether seamless or welded should be free from scale, dirt, specks, longitudinal seams, laminations, grooves and blisters, both internally and externally.

SEAMLESS COPPER TUBES

The material used is copper, 99.5 percent pure, the tubes being made from a cast ingot by hot piercing and rolling, and finished by cold drawing in such a manner as to give the necessary physical properties.

All steel tubes which have closed ends have a small hole drilled in each end to permit the enamel to enter, and after tubes are drained the holes are plugged. In cases where the enamel is baked on the plugging of holes is done after the baking. The method of baking is described under the heading, "*Enameling and Painting of Metal Parts.*"

Note: All steel tubes are rust-proofed before enameling by zinc coating.

BRAZING MATERIAL

The specification covering brazing spelter is as follows:

Copper	68.0 to 72.0 per cent.
Lead	0.3 per cent.
Iron	0.1 per cent.
Zinc	Remainder.

Not over 1.25 per cent impurities allowed.

The wire in sizes from 0.187 to 0.25 inch diameter. The above composition applies to granulated spelter. The copper entering this alloy shall be 99.95 pure; the zinc of Virgin spelter.

CHAPTER XI

Enameling and Painting Metal Parts

Q. What kind of paint is used to paint aircraft fittings?
A. Naval gray enamel.

Q. What is the composition of the above enamel paint?
A. The enamel shall contain 25 to 40 per cent of pigment, the remainder to be high grade, water-resisting spar varnish.

The pigment shall consist of white lead or zinc oxide or a mixture of the two, tinted with carbon black or lamp black to produce the required shade, the whole to be finely ground.

The enamel shall not weigh more than eleven pounds per gallon, and the color be the standard low visibility gray.

Q. How many methods are there for applying this paint to fittings?
A. There are three methods as follows: (1) By the use of a brush, (2) by dipping, (3) by spraying.

The brush or dipping methods require no description other than sufficient time should elapse between applications to allow same to become firmly set before any further application, all fittings receive two coats of naval gray enamel. The enamel shall be baked on where possible. Hollow metal parts, such as control horns, tubes, etc., shall be coated inside by filling with enamel and allowing it to drain out. Tubes having closed ends shall have a small hole drilled in each end to permit the enamel to enter, and after the surplus enamel has drained and the coating dried the holes shall be plugged. In cases where the enamel is baked on the plugging shall be done after baking.

Enameled parts which show bare spots after assembly shall be touched up with naval gray enamel and allowed to air dry.

The spraying and baking process is considered the best and can be done more rapidly than either of the other two methods. The process consists of placing a large number of fittings on a sheet of iron supported by metal horses, the same being placed in a furnace like enclosure, and large fittings suspended by wires on a rack. About 6 feet overhead there is a paint container holding from 3 to 5 gallons of paint which flows downward by gravity through a hose to which a spray gun is connected. A compressed air line hose is also connected to the spray gun, the end of the gun has three holes in same, the center hole from which the air is ejected being $\frac{1}{32}$ inch in diameter and the hole on each side for the ejection of the paint being somewhat smaller than the air hole. This arrangement of the holes produces a fan shaped spray—the spray gun having a trigger which starts and stops both flow of air and paint; the fittings having been placed as before stated are sprayed and turned until all parts are coated, then the enclosure is closed and the temperature of enclosure brought up to 150 to 200° F., by means of electricity, this being an electric furnace. There are other furnaces that can be used for this purpose but the electric is considered best. One hour at the above temperature is usually sufficient to dry or bake the first coat. The above process is repeated with the second coat, the latter coat usually requiring a somewhat longer time to bake than the first or priming coat. Black enamel is applied the same way.

Turnbuckle barrels, shanks, shackles, bolts, hub-fittings, or threaded terminals are not painted.

Enamel paint well applied should show a uniform coating, no lumps, no flaking, and firmly adhering. A good test for enamel consists of bending material without breaking the enamel; there are other tests prescribed to determine resist-

ance to water, gasoline, hardness, etc., which are of value only to inspectors in conducting tests.

BLACK ENAMEL

Q. For what purpose is black enamel used and what is its composition?

A. Black enamel is intended for general use on aircraft fittings, such as handrails, small metal parts, etc. It may be used either as an air drying or baking enamel. It is composed of spar varnish with 5 per cent of carbon black added.

Q. What is wire and cable enamel and for what purpose is it used?

A. It is an enamel composed of spar varnish with 5 per cent of pure American blue (ferri-ferro cyanide). This enamel is intended for use on fixed external wires or cables, fixed internal hull wires or cables, and all internal wing wires or cables.

When dry, it presents a semi-transparent blue film, can be applied by brush or dipped and allowed to drain.

CHAPTER XII

Fabrics and Their Application

Q. How many kinds of fabric are used in seaplane construction, and where used?

A. There are three kinds of fabric used in seaplane construction, namely, linen, (Grade "A"), linen, (Grade "B"), mercerized cotton, (Grade "A"), and cotton sheeting. Grade "A" linen is used for the covering of wings, rudders, elevators, stabilizers and ailerons. Grade "B" linen is used for fuselage covering, top, bottom, and sides. Grade "A" mercerized cotton is used for all purposes for which both Grade "A" and Grade "B" linen are used. Cotton pontoon sheeting is a fabric used between the inner and outer layers of the bottom planking of flying boats, on pontoons between the inner and outer layers of deck planking, as well as the inner and outer layers of bottom planking.

Q. What are the characteristics of the fabrics mentioned?

A. The linen, both grades "A" and "B", are made of the finest unbleached flax fiber, and are distinguished from each other by thread count and tensile strength. Grade "A" linen must have at least 90 threads to the inch in warp, and not more than 105 threads to the inch in the filling. Grade "B" linen must have at least 60 threads to the inch in warp, and not more than 90 threads to the inch in filling. The fabric under normal moisture conditions must not weigh more than 4.5 ounces per square yard, width not less than 36 inches. The linen is tested for tensile strength by cutting samples from various bolts of cloth, 8 inches in length and $1\frac{1}{4}$ inches in width, then pull off threads on both sides of

sample until it measures 1 inch in width; place sample between upper and lower jaws in a test machine with 6 inches between the jaws, allowing 1 inch for gripping by the jaws at each end. The samples are cut in both directions from the bolt, in order that both warp and filling strength can be determined, the pulling jaw to move at a rate of 12 inches per minute during test. The minimum strength shown by grade "A" linen samples for both warp and filling shall be 75 pounds. Grade "B" linen shall show a minimum breaking strength, for both warp and filling, of 65 pounds.

Grade "A" mercerized cotton is manufactured from staple cotton not less than $1\frac{1}{2}$ inches in length. There shall not be less than 80 threads and not more than 84 threads per inch in both warp and filling. To be of plain weave, and not weigh more than 4.5 ounces per square yard under normal moisture conditions; width 36 inches. Samples are cut from bolts to be tested from both directions. The test samples for cotton are longer than those for linen, being 12 inches in length with 8 inches space between pulling jaws, which travel at a speed of 12 inches per minute during test, and shall show a breaking strength of 80 pounds for both warp and filling. It is to be noted that this cotton fabric is stronger than linen fabric of either grade. The cotton sheeting referred to, that is used on flying boats between bottom planking, is of no special manufacture, except it is of high grade. Nainsook of high commercial grade is also used between deck and bottom layers of planking of pontoons. The following is the latest practice in vogue for covering the various parts of an aircraft with fabric:

Thread used for fastening the fabric to ribs and other parts of the machine shall be heavy linen thread and waxed before using.

Thread used for machine stitching of seams shall be silk thread, grade "B."

Thread used for hand stitching of seams shall be light linen thread, and shall be waxed before being used.

Tape used over lacing, or for the protection of edges, covering of tacking, or similar purposes shall be made from linen or cotton. The tape shall be of sufficient width for the purpose for which it is to be used. The edges of the tape shall be frayed by extending the filling threads $\frac{1}{4}$ to $\frac{1}{2}$ inch beyond the body of the tape on each side.

The special reinforcing tape used under lacing loops shall be linen or cotton tape $\frac{1}{2}$ inch wide of an approved quality and strength.

Dope used for cementing of tape to fabric shall be the same dope as is used for the shrinking of the fabric.

Fabric used for pontoon, hull, or float covering shall be cotton pontoon sheeting of an approved quality.

The fabric covering shall be applied to the wings and auxiliary surfaces, so far as is practicable, by the envelope method. An envelope shall be made by sewing the fabric together. This envelope shall be drawn over the surface to be covered, drawn taut, and the open part securely stitched. After completion of the operation the tension in the fabric must be approximately the same in all directions.

All seams shall be folded-ply seams and shall be double sewed, preferably by means of a double-needle sewing machine, equipped with a folder attachment. Ten stitches per inch shall be used. The row of stitches nearest the edge of each side of seam shall be about $\frac{1}{16}$ inch distant from it and the two rows of stitches shall not be more than $\frac{3}{8}$ inch nor less than $\frac{1}{8}$ inch apart. Seams must not follow ribs so that the lacing would be through or over the seam.

Envelope closing seams shall be made at the trailing edge in preference to the leading edge where practicable.

The fabric shall be applied on the wings with the woof or filling threads running at an angle approximately 90 degrees to the ribs.

The fabric may be applied to the body or auxiliary surfaces with woof or filling threads running at an angle to the center line or ribs, respectively, of approximately 45 degrees or 90 degrees as the contractor may decide. In any case the fabric should be similarly applied to each machine or corresponding part of machine on any order.

Fabric shall be attached to wings and auxiliary surfaces by the tape and lacing method.

Lacing of the fabric to ribs shall extend along the rib to within a distance from the leading and trailing edges equal to the distance between lacing points. Lacing shall be at 2-inch intervals on all surfaces.

Under the lacing loops, on each side of all surfaces with the exception noted, a special linen or cotton tape shall be used. On the upper side of wing surfaces a rattan strip may be used in place of reinforcing tape.

The lacing shall be done by passing the thread through the aerofoil from one surface to the other, including in each loop the rib as well as fabric and reinforcing tape or rattan on each side. The first loop shall be fastened with a slip knot, secured. Each succeeding loop, including the final, shall consist of a half hitch knotted around the part of the thread leading from the preceding loop.

The lacing shall be made with one continuous piece of thread for each rib, the thread carried from loop to loop being located on the upper side in the case of horizontal surfaces. In the case of vertical surfaces, the thread from loop to loop shall be located on alternate side over adjacent ribs. Lacing must be taut at all points when completed and before application of dope.

After completion of lacing, application and drying of the first cost of dope, frayed-edge finishing tape, shall be cemented to the fabric, over the lacing on each side, using dope to fasten it in place.

On all edges of all wing panels and control surfaces the fabric shall be reinforced by a strip of frayed-edge tape running the full length of and folded back over the edge. This tape shall be cemented in place with dope.

Where the fabric is pierced by bolts, etc., it shall be reinforced by means of a patch having edges frayed $\frac{1}{4}$ to $\frac{1}{2}$ inch. This patch shall be applied after the first coat of dope has dried and shall be cemented in place by the use of dope.

Where the fabric is permanently tacked to wood parts it shall be doubled back on itself before tacking, and the tacks used shall be brass, tinned iron, monel metal, or copper 3 oz. tacks.

Where the fabric comes in contact with metal parts, these parts shall be coated with naval gray enamel, and, when possible, shall be baked.

All fabric-covered wings and auxiliary surfaces shall be provided with efficient means for drainage of condensation, etc. The use of rust-proof metal eyelets or grommets through the fabric, located at the normally lowest points in each surface, is satisfactory for this purpose.

Where fabric is used for covering of hulls, pontoons, floats, etc., it shall be drawn taut and cemented in place by means of an approved marine glue. The fabric may be ironed after application to improve the penetration and adhesion of the glue.

After the glue has thoroughly set, the surface of the fabric shall be finished as required. If the surface is sand-papered in the process of finishing, this must be done very lightly and the fabric must not be injured thereby.

Fabric used in the construction of laminated bulkheads shall be cemented in place with an approved marine glue.

Solid or laminated struts shall not be fabric covered. Laminated struts, however, shall be taped at their mid section with a 4-inch band of fabric, and cemented in place with casein or hide glue, preferably the former.

COTTON HULL SHEETING

Use

1. This specification covers the general manufacture of hull sheeting that is applied with marine glue to the outer surfaces of hulls of naval aircraft.

Material

2. The sheeting shall be made from cotton of not less than 1-inch staple.

Manufacture

3. The warp and filling yarns shall be alike. The yarn shall be single ply. There shall be not less than 68 threads per inch in the warp and 72 threads per inch in the filling. The weave shall be plain.

Weight

4. The weight shall not be less than 5.2 ounces per square yard as determined according to the method given below.

Finish

5. The material shall be subjected only to the usual gray room processes.

Tensile Strength

6. The tensile strength of the finished material shall not be less than 55 pounds in the warp or filling as determined according to the method given below.

Methods of Tests

7. The weight specimens shall be exposed to an atmosphere of 65 per cent relative humidity at 70° F., for a period of three hours and the weight determined in this atmosphere.

The tensile strength shall be determined from five strips 6 inches long by $1\frac{1}{4}$ inches wide, cut from both the warp and filling directions of the fabric. These strips shall be raveled to 1 inch in width and allowed to remain in an atmosphere of 65 per cent relative humidity at 70° F., for a period of three hours and then tested in this atmosphere. At the end of that time the specimens shall be placed in the clamps of the testing machine with 3 inches between clamps and caused to rupture by moving the pulling clamp at the rate of 12 inches per minute.

COTTON PONTOON SHEETING

Use

1. This specification covers the requirements for cotton sheeting to be used between the inner and outer skins of pontoons and similar construction on naval aircraft.

Material

2. The sheeting shall be made from cotton of not less than 1-inch staple.

Manufacture

3. The warp and filling yarns shall be alike. There shall be not less than 100 threads nor more than 108 threads per inch in either warp or filling. The weave shall be plain.

Weight

4. The weight shall be not more than 3.75 ounces per square yard as determined according to the method given below.

Finish

5. The material shall be subjected only to the usual gray room processes.

Tensile Strength

6. The tensile strength of the finished material shall be not less than 45 pounds per inch in either the warp or filling as determined according to the method given below.

Methods of Test

7. The weight specimens shall be exposed to an atmosphere of 65 per cent relative humidity at 70° F., for a period of three hours and the weight determined in this atmosphere. The tensile strength shall be determined from five strips 6 inches long by $1\frac{1}{4}$ inches wide, cut from both the warp and filling directions of the fabric. These strips shall be raveled to 1 inch in width and allowed to remain in an atmosphere of 65 per cent relative humidity at 70° F., for a period of three hours and then tested in this atmosphere. At the end of that time the specimens shall be placed in the clamps of the testing machine with 3 inches between clamps and caused to rupture by moving the pulling clamp at the rate of 12 inches per minute.

FIREPROOFING OF AIRPLANE FABRIC

Previous to the application of Acetate Dope as described elsewhere in this book, the fireproofing of fabric on fuselages and wings consists of the fabric being coated with a 15 per cent solution of commercial ammonium phosphate. The solution is prepared by dissolving $1\frac{1}{2}$ pounds of commercial ammonium phosphate in a gallon of cold or lukewarn water. The solution will always have the odor of diluted ammonia water so it should be kept (preferably) in closed vessels, otherwise the evolution of the ammonia will change the nature of the compound. The best procedure is to prepare just enough solution to treat the desired quantity of fabric.

The fabric may be treated after it is on the airplane by brushing the ammonium phosphate solution into the fabric or before placing it on the airplane by immersing the fabric in the solution. If the first method is used the fabric should be thoroughly saturated with the solution and then sufficient time should be allowed for the fabric to dry thoroughly before the application of the dope. If the second method of treatment is used the fabric after immersion should be suspended under tension so that it will dry free of wrinkles.

The fireproofing of airplane fabric as above described is now the standard practice on all airplanes now under construction.

The following navy standard doping system shall be used on all fabric-covered surfaces of all airplanes (excepting only such cases where the fabric is glued in place, as is the case with fabric-covered hulls). On all fabric two coats of cellulose acetate dope shall be applied. This shall be followed by the application of a sufficient number of coats of cellulose nitrate dope to obtain satisfactory tautness and finish but in no case shall less than two nor more than four coats of nitrate dope be applied. Sufficient drying time shall be allowed between each of the coats of dope (about 30 minutes.)

After the last coat of dope has dried for not less than 12 hours aluminum paint shall be applied, two coats being used on all vertical surfaces, two coats on upper side and one coat on the lower side of all horizontal surfaces.

Q. How would you repair large or small tears in wing fabric?

A. In making repairs to a large rip or tear, sew tear together using No. 30 linen thread and the baseball stitch. After that is done apply acetone, which is a solvent to remove paint, dope, etc. If place to be repaired is close to a rib, cut out the patch to be applied sufficiently large enough

to extend beyond the rib about 3 inches. Apply a coat of dope over the surface that has been cleaned, and stitch patch in place, having frayed its edges, then dope over same and paint as rest of wing. If tear was adjacent and parallel to the rib, a few lacings should be made around the rib and about 4 inches apart in between previous lacings. Tape over lacing for a small tear same as above. When a tear occurs near a fitting it is best to remove the fitting in order that a proper repair can be made.

Q. What precautions are necessary when covering a new wing or re-covering an old wing?

A. It is important to have wings or any fabric covered part straight and in line before covering and doping, otherwise it is extremely difficult to straighten same if twisted or out of line after covering and doping. If care is taken to give the fabric a uniform tension before doping, and dope is applied uniformly, there is very little danger of twisting the panel, but if such does happen it may be corrected by two methods, as follows: By applying more dope to increase the tension at some slack point which may correct the twist, or if the twist is induced by too much tension in some part of the panel, use acetone to slacken same and weight panel until it comes to its proper shape and will remain so. After doping, in all cases stand panel on its leading edge.

CHAPTER XIII

Material Used in the Construction of H-16's and Other Flying Boats

Keel. Ash—possible substitute white oak, rock elm.

Keelson. Basswood—possible substitute white pine.

Floors. Basswood—possible substitute white pine.

Sternpost. Ash—possible substitute white oak, rock elm.

Breast hooks. Ash—now made of metal.

Longerons. Ash.

Sidewalk beams. Spruce—possible substitute Douglas fir.

Stringers, forward, 7 foot. Ash—possible substitute white oak, rock elm.

Stringers, after, 18 foot. Spruce—possible substitute Douglas fir.

Note: The ash and spruce stringers are spliced together.

Nose frames. Ash—possible substitute white oak.

Seam battens. Ash—possible substitute white oak.

Side planking. 3 ply Haskell veneer.

Shelf stringers. Ash.

Bulkheads. 3 ply Haskell veneer.

Washboards. Spanish cedar.

Nose planking. Spanish cedar.

Fin top framing. Ash—possible substitute white oak.

Gunners cockpit combing. Ash—possible substitute rock elm.

Gunners cockpit backing. Ash—possible substitute rock elm.

Fin stringers. Ash—possible substitute, white oak—rock elm.

Bulkhead stiffeners. Spruce—possible substitute Douglas fir.

Diagonal pillar braces. Spruce—possible substitute Douglas fir.

Beam struts, center. Spruce—possible substitute Douglas fir.

Fin planking top. Haskell veneer.

Bottom and step planking. Spanish cedar.

Tank stringers. Spruce—possible substitute fir.

Tank rings. Ash—possible substitute white oak, rock elm.

Tank floors. Spruce—possible substitute fir.

Floor bearers. Spruce—possible substitute fir.

Floor slats. Spruce—possible substitute fir.

Seat back brace. Spruce—possible substitute fir.

Foot rest. Spruce—possible substitute fir.

MOULDINGS

Fin edge. Ash.

Fin top corner. Mahogany.

False keel on bottom. Ash.

PARTS TO BE BENT

Bow keel, longerons, outer fin members or chine, bow combing, nose ribs, floor stringers, tank rings, deadwood wood for sternpost, seam battens, breast hooks if made of wood.

The above woods are practically the same used in the construction of the F-5-L type of flying boat, and it is to be remembered that in replacing or repairing any broken or damaged part to use a similar material in doing same, or one of the substitutes permitted. Do not use spruce or pine to replace a section of ash or oak, and where replacing a bent or curved piece of ash, oak or rock elm, the piece of material

must be steamed and bent to shape before being used, otherwise you set up what is known as an initial stress, which has a tendency to tear away from its fastenings or throw something out of line.

In the construction of the bottoms of all types of pontoons, or flying boats, are what are knows as steps. In pontoons for seaplanes there is one step, it being a break in the form of the bottom about two-thirds the length of pontoon from the nose, and aids in breaking the suction when getting off the water. The larger type of flying boats have two steps on each side of keel, shaped like an elongated V, and consists of securing several stringers to the boat's bottom, the thin or tapered ends pointed forward, and on the rear end measuring $2\frac{1}{4}$ inches. This is planked over, the forward ends being flashed with sheet copper, thus offering no resistance to the forward motion to the boat. It can be seen that this forms a long V shaped pocket on the bottom of the boat, and there are two of these on each side of the V bottom. In addition to the foregoing, there is provided what is known as breather tubes to break the vacuum, thus permitting the seaplane or flying boat to leave the water readily. In the pontoons they are installed a few inches abaft the step, and are placed vertically, running from the top to the bottom of the pontoon, one on each side of the keel about 6 inches therefrom. These breather tubes are made of light sheet copper, the ends being flanged and secured to the top and bottom planking, tubes being approximately 2 inches in diameter. The H-16 has no breather tubes, but two steps only. The H-S-2-L has one step of a similar design as a pontoon, and has two breather tubes. These are placed on the inside of the hull in a vertical position and get air through the cockpit openings. The original design for the F-5-L type of boats did not call for breather tubes, but some were later installed similar to those in the H-S-1-L type; also breather

tubes have been placed on the fins, close in to the side planking between the top and bottom fin planking.

It is to be noted that, in the construction of the rear part of an H-16 or F-5-L type of flying boat where the fuselage type of construction comes into play, the struts between the upper and lower longerons on each side are of metal tubing, also the transverse braces between the upper longerons are metal. This is done in order to get greater strength, and in order to facilitate fastening to these struts and braces they are covered with two pieces of spruce wrapped with tape and dope, thus making same rectangular in section. Metal tubes of similar design but not wood covered are used in the place of compression ribs in the construction of the large and heavier type of wing panels.

CHAPTER XIV

Glues Used in Aircraft Construction

Q. How many kinds of glue are there used in aircraft construction?

A. Three kinds as follows: Certified hide glue, certified casein glue, marine glue.

Q. Where are the above named glues used?

A. Certified hide glue is used for all high class work where non-water resisting glue is permitted, such as propellers, laminated struts, wing spars, splices, etc., or where parts do not come in contact with water; this glue is also used in glueing veneer and plywood together. The method for mixing and applying this glue and the necessary precautions to be taken with same are described in detail under the description of the manufacture of a propeller.

Casein glue is used for all purposes that certified glue is used for except propellers. It did not come into use until the latter part of 1918, the basis of this glue being powdered dry milk, the other components being a trade secret. The formula is said to have been discovered by two brothers who resided in Switzerland, and the formula purchased by an American concern. Tests have proven that if this glue is handled as per manufacturer's directions it is the strongest glue known in the world today. The writer has witnessed tests conducted with this glue wherein three blocks of wood were glued together and a load applied in a test machine on the center block, and the outer blocks would give way without disturbing the glue. However, this glue must never be used unless the person using same is familiar with the method

of mixing and applying same. In general this glue is mixed with water, and must be applied within 30 minutes after mixing, otherwise it will lose its physical properties.

Marine glue is used for securing the fabric to the hulls of H-S-1-L flying boats, also in connection with the fabric placed between the inner and outer layers of bottom planking, the process of application being to apply a coat of glue to the under side of the first layer of planking, lay on the fabric smoothly, then give fabric a coat of glue before placing the outer layer of planking in place. The properties of this glue are that it is water resistant, being in contrast to the other mentioned glues which set hard and firm, whereas marine glue does not, but remains elastic.

Note: No other glues should be used on aircraft, unless it is authorized by the Bureau of Aeronautics.

CHAPTER XV

Dopes and Solvents

Q. How many kinds of dopes and solvents are there, and for what purpose are they used?

A. Three kinds of dope and two kinds of solvents are used on aircraft: Acetate dope on fabrics used on airplanes to tauten and secure greater fire proofing qualities; Nitrate dope is used to tauten, strengthen and make the fabric impervious to moisture; Airship dope is used on lighter-than-air craft, such as airships, kite and free balloons—it closes the pores in the fabric and lessens diffusion. Airship dope thinner and solvent is the same material, being used to thin airship dope when it gets too thick to apply readily either by hand or spray gun. It is also used for removing dope from airship fabric when patches or similar repairs are to be made. Dope solvent is used for removing enamel and dope from wing and tail surfaces of airplanes when repairs are to be made to the fabric.

Note: In many cases it is very difficult to tell the difference between the cellulose acetate dope and cellulose nitrate dope. The following is a method whereby the two dopes may be distinguished.

Pour a small quantity of the dope upon a glass or smooth metal plate. The dope will gradually solidify with the formation of a film. Allow this film to dry for at least 24 hours and then remove it from plate, set fire to the film and note the rate of burning. If the film has been made from nitrate dope it will burn with great rapidity and with a flashy flame. If made from acetate dope the film will burn with a slow steady flame. It is suggested that if the two dopes are

available that this test be conducted as this will give an idea of their comparative rates of burning and will make it less difficult to distinguish an unknown dope.

Care should be taken to see that dope is in good condition before being applied to the cloth as the constituents of the dope deteriorate with age. If the dope has become darkened it should be tested for acidity before being used. If facilities are not available a half gallon sample should be forwarded to the Bureau for test. In all events the dope should be tested on a small piece of cloth before being applied to the cloth covered parts.

CHAPTER XVI

Aircraft Paints and Insignia

Q. How many kinds of paint, dope or varnish are used on an aircraft, and where used?

A. There are six kinds of paint used on aircraft, namely: Naval gray enamel for hulls and pontoons and struts if painted, also fittings. Aluminum wing enamel for wings; black paint for numbers, also black enamel on fittings; red, white and blue for insignia.

There are two kinds of varnish used: Spar varnish for wing panels before being covered, interior of flying boat hulls (except in cockpits where shellac varnish is used, which is not solvent in gasoline), on interplane struts if not painted like N-9s, and generally throughout the machine.

Shellac varnish is used in cockpits, and as a filler for a first coat for propellers.

AIRCRAFT INSIGNIA AND MARKING

Use

1. The distinguishing insignia and marking herein described are for use on all United States Naval aircraft.

Insignia Design

2. The insignia design shall be a red circle inside of a white five-pointed star inside of a blue circumscribed circle. The construction is obtained by marking off five equi-distant points on the circumference of the circumscribed circle and connecting each point to the two opposite points. The outer parts of the lines thus obtained from the points of the star,

and the red inner circle is made tangent to the sides of the pentagon formed by this construction.

3. *Dimensions.* The diameter of the circumscribed circle shall be 5 feet, except that where the chord length of the wing is less than 5 feet, in which case the diameter shall be equal to the chord length.

4. *Direction.* On vertical surfaces one of the points of the star shall point directly upward and on horizontal surfaces one of the points of the star shall point directly forward.

5. *Color.* The shades of red, white, and blue shall be the same as those used in the United States flag.

Marking

6. *Building Letters and Numbers.* The building letters and numbers to be painted in black on the aircraft as hereinafter described are arbitrary symbols, assigned by the Department for the purpose of referring to a component unit such as the car or the envelope of an airship.

7. *Class Letters and Numbers.* The class letters and numbers to be painted in blue on the aircraft as hereinafter described are arbitrary symbols assigned by the Department to designate the aircraft and should not be confused with the building letters and numbers referred to in paragraph 6.

8. *Example.* Airship car number A-4118 and envelope E-103, when assembled with a set of control surfaces, form airship D-l, i.e., the first airship in the D class. Should manufacturing necessity intervene, any or all of the component parts may be changed, but the completely assembled airship would still be desigated as D-1. A subsequent type would be "E" or "F" class airship.

9. *Piece Numbering.* All individual metallic fittings, except standard parts, such as bolts, nuts, washers, turnbuckles, swaged and stream-line wire terminals and shackles, shall

be marked with the manufacturer's piece number. The number shall be in raised letters when possible and as large as practical.

10. *Manufacturers' Identification Plate.* On each aircraft of any type, there shall be placed on each instrument board a metal plate, transfer, or other convenient means (the size of which shall not exceed 3 inches by 6 inches) the following information:

(1) Name, trade-mark, and address of aircraft manufacturer.

(2) Manufacturers' model and serial number.

(3) Navy model, class, and serial number.

(4) Date of delivery (approximate).

11. The name or trade-mark of the manufacturer shall appear on the aircraft in no conspicuous location other than that specified above, and in any case such other location must be specifically approved in writing by the Bureau.

AIRPLANE INSIGNIA AND MARKING

12. *Insignia.* Four insignia will be placed on the wings of each airplane. One shall be placed on the upper surface of each upper wing, in such a position that the circumference of the circumscribed circle just misses contact with the aileron and one shall be placed on the corresponding position, on the lower surface of each lower wing.

13. Both sides of that portion of the rudder which is in rear of the rudder post shall be painted with three equally wide bands, parallel to the vertical axis of the airplane and colored red, white, and blue, of the shades specified in paragraph 5. The blue band shall be nearest the rudder post, the white band in the center, and the red band at the tail of the rudder.

14. *Marking.* The building letter and number, assigned by the Department and specified in the contract, shall be

painted in 3-inch black figures on each side of the rudder, at the top of the white band. Also the building letter and number shall be placed, in 12-inch black figures, on the sides of the body, midway between wings and rudders.

15. All struts shall be numbered at the bottom, in 1-inch black figures, and corresponding black numbers shall be painted on the top of lower wing panels close to the strut fittings. The front outermost strut, on the right of the pilot, shall be numbered (1), and all the remaining front struts shall be marked in order, from right to left, with consecutive odd numbers. The rear outermost strut, on the right of the pilot, shall be numbered (2) and all the remaining rear struts, from right to left, shall be marked with consecutive even numbers.

16. A code of letters and figures shall be used to designate the doping system and date of application. These designations shall be black letters 1 inch high and placed on the underside of the fuselage, wings, and control panels. The code provides for a letter or letters to be assigned to each finishing material, with the figures following to indicate the number of coats and date of completion. The finishing materials, in accordance with Bureau of Construction and Repair aeronautical specifications, have been given the following designating letters:

Acetate dope	A D
Nitrate dope	N D
Naval gray enamel	E
Spar varnish	V
Wood filler	W
Shellac	S
Aluminum wing enamel	A

17. For example, the code AD2, ND3, E2, 10-8-18 would mean: Acetate dope, two coats; nitrate dope, three coats;

naval gray enamel, two coats; the work being finished October 8, 1918.

AIRSHIP INSIGNIA AND MARKING

18. *Insignia.* Two insignia, 5 feet in diameter, will be placed on the envelope of each airship, one on top and one on the bottom, the center of each insignia being on a line established by the intersection of a vertical longitudinal axial plane with the envelope. The center of the top insignia shall be on this established line, and at the greatest diameter of the envelope. The center of the bottom insignia shall be on the established line, 3 feet back of a point midway between the front of the car and the tip of the bow of the envelope, measured horizontally.

19. The rudders and elevators of each airship will be marked in a manner similar to that required for airplane rudders in paragraphs Nos. 13 and 14. The bands shall not exceed 5 feet in length, or 18 inches in width, and where there is more than one rudder only the outboard side of each outboard rudder will be marked.

20. *Marking.* The class letter and number designating each airship, assigned by the Department and specified by the contract, together with the words, "U. S. Navy," where hereinafter specified, shall be painted on fabric and affixed to the envelope. Light empennage fabric, preferably of the same color as the envelope, shall be used.

21. Three sets of class letters and numbers shall be affixed to the envelope, one set on each side, preceded by the words "U. S. Navy," the center of the letters and wording being over the center of the car, and one under the bow, the centre being 10 feet 6 inches forward of the center of the lower insignia.

22. The letters and figures shall be 54 inches high and the

color used shall be blue, of the shade of blue used in the United States Flag.

23. The building letters and numbers, designating each set of control surfaces and corresponding stabilizers or fins, shall be painted in 3-inch black letters, on each side.

24. The letters and numbers, on the upper surfaces, on either right or left side, shall be so placed that the bottom of the letters and numbers is outboard in each case.

25. The letters and numbers, on the under surfaces, on either right or left side, shall be so placed that the bottom of the letters and numbers is inboard in each case.

26. The letters and numbers, on the vertical surfaces, shall read from forward aft on the left side and from aft forward on the right side.

27. The letters and numbers, on the elevators, shall be painted on the white band, in such location that the top of the letters or numbers is 3 inches from the inboard margin of the band.

28. The letters and numbers, on the rudders shall be painted on the white band, in such location that the top of letters or numbers is 3 inches, from the top margin of the band.

29. The letters and numbers, on the fins or stabilizers, shall be painted on their surfaces in direct line with the letters and numbers, on the control surfaces and 6 inches forward of the rear edge, of the fin or stabilizer.

30. The building letter and number of the car, assigned by the Department and specified in the contract, shall be painted in 3-inch black figures on each side of the car, at about the midpoint of its length and level with the top longitudinal member.

31. The building letter and number of the envelope, assigned by the Department and specified in the contract, shall be painted in 3-inch black figures, only on the lower side and

just aft of the lower insignia. The top of letters and numbers shall be the nearer to the insignia. In case the color of the envelope is such that black figures are not readily distinguishable, there shall be painted a white background, with 1-inch margin, about these building letters and numbers.

FREE BALLOONS, INSIGNIA AND MARKING

32. *Insignia.* For United States Navy spherical balloons two insignia, 5 feet in diameter, shall be placed on the envelope, one at each end of a diameter which is inclined 45° to the vertical axis of the balloon.

33. *Marking.* The words "U. S. Navy" shall be painted on fabric and affixed to the envelope centered on each end of a horizontal diameter, in a vertical plane, perpendicular to the plane passing through the centers of the insignia.

34. Light empennage fabric, preferably of the same color as the envelope shall be used. The letters shall be 54 inches high and painted with the shade of blue same as blue used in the United States Flag.

35. The building letters and numbers, assigned by the Department and specified in the contract, shall be painted on the envelope 3 inches below the lower insignia, the letters and figures to be black, 3 inches high. In case the color of the envelope is such that black figures are not readily distinguishable, there shall be painted a white background, with 1-inch margin, about these building letters and numbers.

KITE BALLOONS, INSIGNIA AND MARKING

36. *Insignia.* Two insignia, 5 feet in diameter, shall be placed on each kite balloon, one on top and one on bottom of the envelope, the center of each insignia to be at the intersection of a vertical plane, through the longitudinal axis,

with a vertical plane through the greatest diameter of the envelope.

37. *Marking.* The words "U. S. Navy" shall be painted on fabric and affixed to each side of the envelope, on the longitudinal center line, approximately midway between the nose and the forward end of the empennage.

38. Light empennage fabric, preferably of the same color as the envelope, shall be used. The letters shall be 54 inches high and painted with the shade of blue same as blue used in the United States Flag.

39. The building letters and numbers, assigned by the Department and specified in contract, shall be painted on the envelope 3 inches aft of the lower insignia, the letters and figures to be black, 3 inches high. In case the color of the envelope is such that black figures are not readily distinguishable, there shall be painted a white blackground, with 1-inch margin, about these building letters and numbers.

MARKING OF PIPES

In addition to the foregoing, the various pipes of an aircraft are painted as follows: All piping shall be marked with colored bands, about one-half inch wide, painted on pipe, near each end and at intermediate points not over 24 inches apart, in accordance with the following system:

(a) Fuel pipes: Red.
(b) Oil pipes: White.
(c) Air (except starter) pipes: Blue.
(d) Water pipes: Yellow.
(e) Starter pipes: Black.

CHAPTER XVII

Aluminum and Its Alloys

Q. For what purpose is sheet aluminum used?

A. Sheet aluminum is used for cowling around engines on the forward part of the fuselage, for streamlining in some instances, back rests for scarf ring gun mounts.

Q. What are the characteristics of sheet aluminum?

A. Sheet aluminum should show by chemical analysis a minimum of 98 per cent aluminum. Test specimens cut in any direction from a sheet should show results as shown in the following table:

CONDITION	THICKNESS		TENSILE STRENGTH (MINIMUM)	ELONGATION (MINIMUM) IN 2 INCHES 50.8 MN. PER CENT
	Gage number (B. & S.)	Inches	Pounds per square inch	
Hard-rolled.......	10 to 26	0.102 to 0.016	22,000	2
Half-hard.......	10 to 16	0.102 to 0.051	18,000	7
	18 to 26	0.040 to 0.016	18,000	5
Soft-annealed...	10 to 16	0.102 to 0.051	12,000	30
	18 to 22	0.040 to 0.025	12,000	20
	24 to 26	0.020 to 0.016	12,000	10

Good sheet aluminum in addition to the above should be sound, flat, free from buckles, seams, discolorations or other defects. A test piece of soft-annealed sheet aluminum should bend back against itself without cracking. Half hard sheets

should bend through an angle of 180° on a radius equal to the thickness of the sheet without cracking.

Tolerances on thicknesses of sheets are permitted as follows:

THICKNESS, AMERICAN WIRE GAGE (B. & S.)	TOLERANCES
	inch
10–11	0.003
12–14	0.003
15–17	0.003
18–20	0.002
21–23	0.002
24–26	0.002

Aluminum alloy sheet should for temper No. 1 show by tensile 55,000 pounds per square inch, sheet tempered No. 2, 50,000, the elongation being 2 inches in 15 and 20 inches respectively. Strips cut in either direction from either No. 1 or No. 2 tempered sheets should withstand cold bending through an angle of 180°, over a diameter equal to 4 times the thickness of the sheet.

It is to be noted that hammering of sheet aluminum hardens same and causes it to become very brittle; this is to be avoided as much as possible.

Some parts of aircraft fittings are made from ingot aluminum, or aluminum alloy bars, the alloy bars being made from the ingot aluminum which has to be 99 per cent pure aluminum. Ingot aluminum is used in the manufacture of castings, aluminum bronze, manganese bronze, etc. The step casting on N-9 pontoons is of aluminum alloy. The bracket upon which the rudder bar mounts is of the same material. Pulleys on land machines are made of aluminum alloy, but not on flying boats or seaplanes, the latter being made of high grade brass, bronze or canvas bakelite.

A good aluminum alloy bar should show by test a tensile strength of from 45,000 to 55,000 pounds per square inch:

1-inch in diameter	55,000
$1\frac{1}{2}$-inch in diameter	50,000
2-inch in diameter	45,000

CHAPTER XVIII

Properties and Use of Duralumin

PHYSICAL PROPERTIES

The outstanding property of duralumin which makes it suitable for aircraft work is that it combines strength with low specific gravity.

The following are the general physical properties of duralumin:

Specific gravity	2.80 to 2.85
Weight	0.100 to 0.102 lb. cu. in.
Melting point	650°C. (1200° F.)
Coefficient of linear expansion,	0.0000226 per deg. C. (0.0000126 per deg. F.
Modulus of elasticity	9,400,000 lb./sq. in.
Tensile strength	52,000 lb./sq. in.
Yield point in tension	32,000 lb./sq. in.
Compressive strength	44,000 lb./sq. in.

The electrolytic metals negative to duralumin are copper, brass, bronze, iron and steel. These metals should never be joined to duralumin where subject to moisture.

Duralumin depends entirely on heat treatment for its remarkable physical properties. When annealed by heating to a temperature of between 350°C. and 380°C. (660°F. and 720°F.) and quenching in water or oil, it becomes plastic and may be forged or stamped, solid drawn in the form of sections or tubes, or rolled into sheets.

When normalized by heating to about 500°C. (930°F.) and quenching in water or oil, the physical properties are very similar to those of mild steel, the strength being about 52,000

pounds per square inch and the elongation 15 per cent in 2 inches.

MANUFACTURE

Tubes and sections under 0.05 inch thick are made by solid drawing, thicker tubes and bars by an extrusion process like that used for brass and similar alloys. Duralumin may be forged and stamped, with a strength after normalizing which varies from 48,000 to 56,000 pounds per square inch according to the size of the piece.

HEAT TREATMENT

Correct heat treatment is essential if the best properties of the metal are to be developed to their fullest extent.

The best method of heating the material uniformly is by means of a salt bath. This comprises an iron or steel trough, in a brick setting, partly filled with a mixture of potassium and sodium nitrates and heated by gas jets. The heat necessary is greatly reduced if a sheet iron lid protected by a layer of asbestos, is lowered over the bath at such times as articles are not being placed in or taken out of it.

Accurate thermometers or pyrometers should be inserted in the salt mixture to insure a correct temperature.

The articles to be heat treated are left in the molten salt until they are uniformly heated to the correct temperature and are then withdrawn and quenched in water or oil.

The material is not injured by leaving it in the bath for a longer time than is actually necessary, provided that the temperature is not allowed to alter. On the other hand, ample time should be allowed for the articles to heat through.

ANNEALING

Whenever any cold work is to be done on duralumin, it must be annealed. If considerable cold work is to be done,

the material, like brass, must be annealed between successive operations.

For annealing, the temperature of the bath should be between 350°C. and 380°C. (660°F. and 720°F.). The minimum number of minutes for which the article should be left in the bath is 80 times the square root of its least dimension in inches, that is, of the thickness in case of a plate, or of the diameter in case of a bar.

At the end of the specified period the article should be taken out and immediately quenched, either in water or in oil of good quality.

As the effect of annealing does not last long, any work to be done on the annealed parts should be done within an hour after annealing.

NORMALIZING

For final treatment the material should be uniformly heated to 480°C.-490°C. (895°F.-915°F.) and then quenched in water or oil. The minumim number of minutes for which the article should be left in the bath is 60 times the square root of its least dimension in inches.

After treatment the material remains soft for about an hour and then gradually hardens until in about a week the full strength is reached. Hence if any test pieces are taken from a heat treated article they should not be tested until at least a week after treatment. Once hardened, the material remains so permanently.

On account of this property of remaining soft for a time after heat treatment and then becoming hard, it is possible to straighten while still soft, articles of duralumin which have buckled or warped during heat treatment.

A considerable saving can often be made by working the material after final heat treatment. The general rule in this respect is that the normalizing temperature should be used

only when but one operation after heat treatment is required to finish the part. If more than one operation is required, the annealing temperature should always be used.

In heat treating duralumin, it is essential that a reliable pyrometer be used and that the temperature of the bath be carefully watched. If the metal is heated above 550°C. (1020°F.) the strength is much reduced and the metal is made very hard and brittle. Even when treated between 520°C. and 550°C. (970°F. and 1020°F.), the metal becomes somewhat unreliable.

HEAT TREATMENT FOR FORGING AND STAMPING

The material should be heated in a muffle oven to a temperature of between 380°C. and 420°C. (715°F. and 790°F.), and, if possible, a pyrometer should be arranged to read the temperature. If a pyrometer is not provided, the correct temperature must be found by experience, this temperature being such as will brown a piece of ordinary newspaper. The forging or stamping should be done as soon as the metal leaves the muffle. No definite rule can be given for the time when the metal requires reheating, but it soon becomes evident when the metal becomes too cold, as it gives a decided ring and usually cracks. The final heat treatment for drop forgings should always be carried out in the salt bath, in order to insure uniform temperature.

MACHINING DURALUMIN

The metal can be turned at the same speed as brass. It does not seize or drag the tool. Kerosene is a good tool lubricant in threading or finishing machine parts of duralumin.

BEHAVIOR OF DURALUMIN UNDER TEST

Duralumin has several of what may be called "false yield points." As the load is applied the material suddenly yields slightly at a low load, but instead of this yield continuing the metal remains elastic and finally the true yield point occurs at a load in the neighborhood of 32,000 pounds per square inch. Often several such false yield points occur before the true yield point is reached. If the load is removed the yield at these lower values remains as a permanent set; if the load is reapplied they do not occur again, and the material obeys Hooke's law up to the elastic limit.

DURALUMIN MEMBERS IN TENSION

Duralumin may be used for any part where a combination of strength with extreme lightness is desirable. Where small holes are drilled in thin material, a small reduction in strength on the material surrounding the holes occurs, this being probably due to the heat produced by the drill.

RIVETED JOINTS IN DURALUMIN

Rivets should be softened for use at the normalizing temperature and should be riveted up within one hour of the heat treatment.

The bearing pressure allowed on the rivets should not exceed 70,000 pounds per square inch, above this elongation of the hole occurs. An ultimate shearing stress of 24,000 pounds per square inch in single shear may be allowed on the rivets. With the very thin plates and members used in aircraft construction it is preferable to use a large number of small rivets rather than a few large ones.

DURALUMIN MEMBERS IN COMPRESSION

As duralumin is a much more reliable material than wood, more refinements in reducing weight can be adopted in the design of duralumin struts.

The principal use for duralumin at this time is for the construction of the frame work in rigid and semi-rigid airships. and it is being used to a small extent in heavier-than-air craft.

CHAPTER XIX

Overhaul and Alignment of Aircraft

When the general condition of an airplane, seaplane, or flying boat warrants overhaul due to long usage, or having become damaged while in use, the following is the procedure in connection with overhaul. (1). Disconnect all piping from your engine. Remove engine, and send same to shop for overhaul. (2). Remove outer panels. (3). If a seaplane of the N-9 or R-6 type or any other type of seaplane with a fuselage construction, lift machine from truck by hooking crane or chain fall to the lifting cable which is placed in the center of gravity in all small machines. After truck has been removed, disconnect pontoon struts from fuselage and send same to the joiner or wood-working shop if there is any work needed on the pontoon. The fuselage is then lowered on horses, when the side walk panels, or lower engine sections as they are sometimes called, are removed. Then remove the engine section panel by disconnecting engine section struts from the fuselage. Then remove elevators, rudder, vertical stabilizer and horizontal stabilizer. This is followed by the removal of the fabric from the fuselage, in order that a careful inspection may be made of all fittings and wires connected thereto. This inspection consists of looking for corroded wires, distorted or broken fittings, the slipping of a fitting along the longeron, and a very close examination of the longerons themselves, particularly in the wake of pontoon strut connections where the longeron is liable to become broken from a hard landing. In the event that a longeron is found broken, it will be necessary to remove same and replace with a new one. This means the slackening up of a

large number of wires and fittings in order that same may be removed. It will also be necessary to disconnect all longerons from the tail post, in order that when the machine is aligned that trouble will not be experienced due to one or more longerons having taken up more moisture than some other. Thus, if the longerons are not disconnected from the tail post, in some instances it would be impossible to bring the fuselage in proper alignment.

Having renewed the necessary broken parts, fittings, or wires, and cleaned all fittings (which in a majority of cases show slight corrosion) by the use of a wire brush, give all fittings a coat of red lead paint, allowing same to become thoroughly dry, then coat same either with black enamel paint or Naval Gray Enamel paint. In the meantime the fabric and fittings attached to the wings and tail surfaces is carefully gone over to determine its condition, and if the wings do not warrant recovering, the same are patched if found necessary. Any damaged or badly corroded fittings are renewed, also control horn brace wires, etc., are carefully examined and renewal made where found necessary. It is to be noted that the ribs as well as the veneer on the leading edge is frequently found broken, due to someone having walked thereon. It is necessary that these be gone over carefully in order to determine if they are intact. If such is not the case the fabric is opened up and the necessary repairs made. It is also essential that the tail ribs be examined in the vicinity of the metal trailing edge, which due to condensation of moisture, corrodes very rapidly. This condition frequently necessitates the removal of the fabric entirely in order that steps may be taken to check the corrosion of the metal trailing edge. This involves the removal of the fabric, which is wrapped around the metal trailing edge, the same being scraped and cleaned, then give same a coat of red lead paint, allowing same to dry thoroughly; then re-tape, dope,

and give the fabric a coat of Naval Gray Enamel paint. Where the fabric has been removed in order to carry out the preceding work described, the wing panel is then recovered. The process and description to be followed in recovering is described elsewhere in this work. Naturally, this requires the removal of all fittings, which are afterwards replaced and refitted, the same having been cleaned, painted, and enameled.

The repairs having been completed to any broken parts that may have been found in the fuselage, stranded, badly corroded, or broken fittings and wires having been renewed, the fuselage is ready for alignment. It is again to be noted that the tail post is removed when starting the alignment. The fuselage is then placed on its side on two adjustable horses. The section of the bottom of the fuselage of the forward cockpit is "trammeled," or "trammed" diagonally to see that this section is square. The cross brace wires are tautened so that this section remains square. This operation is followed by "tramming" all of the remainder of the bottom sections all the way aft to the tail, and then "tramming" forward, beginning in the section forward of the forward cockpit to the nose. The next operation is to start from the after cockpit and work aft, "tramming" all sections by means of adjusting the center or "X" brace wires. Then "tram" all top cross brace wires. Then turn the fuselage on its bottom on the adjustable horses. Level the upper longerons of the forward cockpit both transversely and longitudinally by means of transverse non-flexible strips, straight edge, and level.

The four main struts between the upper and lower longerons situated in the forward cockpit, the upper ends of which lean forward, to the lower ends of which the hinge fittings are connected, are then checked for the proper angle. This checking is done by dropping a plumb line from center of bolt at top

of strut, and the distance from the plumb line to the center of the hinge at the bottom of the strut, being regulated by adjusting the side brace wires in the forward cockpit. In an N-9 fuselage this distance should be $4\frac{3}{4}$ inches. This is done on both sides of the fuselage, and the brace wires on both sides in this section given the proper tension.

The proper tension for all brace wires is that they be made sufficiently taut enough to hold the frame work rigid and in place. See that wires are not so taut as to elongate the eyes, etc., and that fittings are not imbedded into the wood work, and that no part of the frame work is buckled or twisted. The forward cockpit having been leveled, as previously described, and the side brace wires in this section adjusted and given the proper tension, the next procedure is to shift your transverse strips and longitudinal level to the next section in the rear of the forward cockpit, and by adjusting the side brace wires throughout to the tail, taking one section at the time, thus bringing the upper longerons level throughout the entire plane.

The next procedure is to align the two engine bearers. This is done as follows: A line is stretched from a portable post just forward of the fuselage to another portable post aft of the tail, the line being stretched close to the side of the fuselage, not touching, and $6\frac{7}{8}$ inches below the top of the upper longerons which have been previously leveled. It is to be noted that this engine bearer alignment to be described is to cover the procedure whereby a Hispano-Suiza motor is the type of engine being used. The top of the engine bearers are brought to the level of the line by means of the brace wires. These brace wires enable this leveling to be accomplished transversely and longitudinally. After all of the foregoing procedure the fuselage is now lined up, but it is essential that the entire alignment be verified, and this procedure is as follows: Place a transverse straight edge over

and resting thereon the forward end of the engine bearers and one at the rear end of the engine bearers, to the center of which a plumb line is dropped within 8 or 10 inches of the floor or concrete as the case may be, then in the center of the transverse braces between the upper longerons at each section as well as through the hinges on the tail post, which has been replaced, thus making a long row of plumb lines hanging from the forward to the after end of the fuselage, then stretch a horizontal line underneath the fuselage and observe carefully to see that all plumb lines just barely touch this longitudinal line. Any variance must be corrected. This can be done by the bottom and top cross brace wires being adjusted so as to pull this section into the line.

After this has been found correct, all brace wires are safety-wired and all nuts and clevis pins are cotter keyed.

The fuselage is now ready for covering with fabric. After the fabric is on, the fuselage is again leveled on the adjustable horses. The leveling of the fuselage at this stage can be accomplished only by means of leveling the engine bearers, as the longerons are covered with fabric and are more or less inaccessible. The fuselage is now in a position for normal horizontal flight.

The horizontal stabilizer is then secured to the tail by "U" bolts, which clamp around the upper longerons and around the beams of the horizontal stabilizer. A diagonal brace on each side of the horizontal stabilizer and underneath is secured to lower longeron and to the forward and aft beams of the stabilizer.

The vertical stabilizer is bolted to the horizontal stabilizer. Its longitudinal direction is exactly in a fore-and-aft line and is pre-determined by the boring of the bolt holes in the horizontal stabilizer. Its vertical position is adjusted by four transverse brace wires which run diagonally down to fittings on the horizontal stabilizer. A tram for each side is used in this adjustment.

The rudder is then secured to the vertical stabilizer by four hinges.

The elevators are next secured to horizontal stabilizer, there being three hinges to each elevator.

The upper engine wing panel section is next secured. This rests upon four struts which, when secured, form a continuation of the four main fuselage struts at forward cockpit which are not at an angle.

The lower engine wing panel sections are next secured to the hinge fittings on each outboard lower side of the forward cockpit main struts. The intermediate wing struts, at the ends of these panels and connecting the upper and lower wings, are then put in place and bolted. The load, lift and stagger wires are then connected up and tautened.

While the riggers are securing these panels the engine crew is installing engine on engine bearers.

To line up wing panels: (Fuselage in normal horizontal flight position on adjustable horses.) Drop four plumb lines, one from each end of each upper engine wing panel section at the entering edge, and one from the same entering edge just clear of the fuselage on each side. A straight edge about 10 feet long is placed on the upper engine wing panel section leveled transversely as shown by a spirit level by means of adjusting the load and lift wires. The stagger is then checked. The entering edge of the upper wing should be $9\frac{13}{16}$ inches forward of the entering edge of the lower wing on an N-9. This is observed by measuring the distance of the plumb line from the entering edge of the lower wing. It is corrected or adjusted by means of the "stagger" wires between the struts. The angle of incidence of the wings in this position of normal horizontal flight is $3\frac{1}{2}$ degrees.

The outboard wing sections are assembled on the floor away from the fuselage. The load, lift and stagger wires are tautened to hold them rigidly together. The cabane, ailer-

ons, control horn and control wires and their leads are all connected and secured.

These outboard wing sections are hung to the center sections by means of hinge fittings. The same process of aligning these outboard sections is continued as was used in the alignment of the center sections.

After the alignment of all these wing sections by means of the straight edge and level there is still a possibility of their being slightly out of alignment. This can be determined by sighting along the entering edge of each wing from a position near the wing tip to see that a straight line is formed. Similarly for the trailing edge.

Now stand about 20 feet in front of the center of the machine. Bring the entering and the trailing edges of each wing in line with the eye and see that no drooping occurs, if so, it is to be taken up by the lift, load, and stagger wires.

As a further check, stretch a wire from the forward center part of the forward outboard strut fitting to the center of the propeller shaft, measuring this distance on each side to see that it is the same. Similarly from the center of the after outboard strut fitting to the center of the tail post.

Connect up all control wires.

See that ailerons are in line with each other for horizontal flight.

See that elevators are in line with each other.

Only $\frac{1}{8}$ inch of play is allowed in all control wires.

Using a chain fall, raise the machine by hoisting sling, place pontoon under it and connect pontoon to fuselage by bolting the pontoon struts to it and to the pontoon. The pontoon is lined up with the fuselage by the tramming process, tramming the strut sections under the forward cockpit first.

The wing tip pontoons are next secured in place.

All turn-buckles are then safety-wired, and cotter pins put

in all bolts, clevis and hinge pins. A careful inspection is made for this as it is very important, as one cotter key or safety wire left off may cost the pilot his life and wreck the machine.

The machine is then ready for an engine test.

For the overhaul of flying boats, such as HS-ls, H-16s, F-5Ls, or any other type, the procedure is as follows: Remove the engine or engines, as the case may be, the outer wing panels, tail units, engine sections. Lift the boat from the truck by means of jacking, horses provided for the purpose being placed under the side walk sections in addition to blocking up the hull proper. In this position the necessary repairs are made to the hull, and the remainder of the inspection and repairs is conducted in the same manner as which they were on the N-9 type.

In connection with the foregoing, careful inspection should be made of all control wires, particularly where they pass through Bowden fair leads or around pulleys, or at any place where they are liable to create friction and become frayed or otherwise damaged, and renew all such wires that are found so damaged. A few days before a flying boat is completed, particularly those which have been undergoing overhaul for some time, it is advisable to put a few inches of fresh water into the interior of the boat in order that the bottom may take up and be tight from the effects of having become shrunk more or less during the period while undergoing overhaul or to test out new work.

CHAPTER XX

Checking Alignment of Seaplanes on Beach

Place machine in horizontal flight position (which is level), sight along entering edge of wings from tip to tip, to see that same is straight, also trailing edges.

Get directly behind the machine and sight over the trailing edge of horizontal stabilizer to wings to see that both are in line laterally.

Drop plumb lines over entering edges of wings to check stagger. By placing yourself about twenty feet in front and in center of machine you can check angle of incidence by sighting underneath the wings on fittings from fuselage out, on both sides.

To see that wing surfaces are at right angle to fuselage, take a steel tape and measure from center of propeller shaft to center of outboard forward strut fitting, on both sides, see that this distance is equal, also take the distance from center of tail post to center of outboard rear strut fitting, see that this distance is equal, on both sides.

Pontoon is lined by tramming brace wires, and taking distance with steel tape from center of nose on pontoon to outboard forward strut fitting on both sides, and from center of tail of pontoon to center of tail post on both sides.

Sight along trailing edges of elevators to see that both are in line; do likewise with ailerons; use all safety precautions such as cotter pinning all bolts and safety wiring all turnbuckles, seeing that all wires are in proper tension, control wires connected up and not allowing over $\frac{1}{8}$ inch play in same.

In case of a machine having dihedral angle same can be checked by using the dihedral board and level; or by stretch-

ing a line from over the upper wing surfaces from wing tip to wing tip directly over the spars or wing beams; and measuring from spars or wing beams up to line from each section or bay, measurements being given on assembly plans of machines.

INSPECTION OF SEAPLANES AFTER FLIGHT

Check up all alignment (see alignment of seaplanes on beach).

Inspect all controls to see that they function properly; all control wires to see that they are not frayed or strands parted. This is most likely to happen where they pass around pulleys and through fair leads.

Inspect all fabric-covered surfaces for holes, and also all wires such as "Flying," "Load," "Stagger," "Drift," "Landing," "Pontoon," "Brace," "Fuselage Brace," seeing that all are in good condition, properly doped, and in tension.

Inspect all woodwork where accessible for splits and breaks, all fittings to see none are broken or bent, examine carefully all hinges of ailerons, rudder, and elevators.

Inspect pontoon for leaks, etc., clean all parts of machine thoroughly, using soap with no alkali in it, as this will injure fabric and paint; pure Castile soap is recommended. Use as little water as possible, as water will get underneath the fabric covered surfaces and injure parts where glue is used, as well as cause woodwork to swell and get out of shape. Keep all parts free from oil and grease, except where used on hinges, controls, etc., as grease will cause the paint to soften and come off, and will also cause the fabric and wood to decay.

In connection with the alignment of fuselage type machines, in order that the machine may be properly aligned it is necessary that the rigger have the assembly plan,which

will give him the proper dihedral, stagger, angle of incidence, etc., in order that he can align the machine in accordance with the dimensions and figures contained thereon. Otherwise, the distance between the top of the engine bearers and top of the longerons would be unknown, and assembly plan is also necessary in assembling a flying boat. The plan is not absolutely essential whereby the rigger is familiar with all the dimensions required.

WING HEAVINESS

Q. How would you correct right or left wing heaviness?

A. The first procedure would be to find out if the wing tip float of the heavy wing was free of water. If no water is found therein, then check alignment of the plane. If same is found correct it will be necessary to slack all load or lift wires on the trailing edge; slack all stagger wires in the heavy wing that lead from the leading edge of the upper wing to the trailing edge of the lower wing from ½ to 1 turn on the turnbuckle. Take up a similar amount on the stagger wires that lead from the trailing edge of the upper wing to the leading edge of the lower wing. This will slightly increase the angle of incidence in the upper wing. This is the only way that this condition can be properly corrected. Right or left wing heaviness has always been a puzzle to many people in the assembly and alignment of aircraft. The cause therefor could not be understood. This condition, however, rarely ever occurs in any type of machine except flying boats and is due to the fact that the side walk beams which pass transversely through the hull of flying boats are not in all cases at absolutely right angles to the boat itself and has a tendency to throw one set of wings slightly in advance of the other. This, however, can be taken care of by the drift wires, owing to the flexibility of the structure. But the principal causes

are that the side walk beams are not in their designed position as to the height from the bottom of the keel; for instance, assuming that the flying boat flies with right wing heavy and if the outer ends of both right and left wings measure the same distance to the bow of the boat, then it is apparent that the right rear end of side walk beam is high. It can readily be seen that the left rear end of side walk beam would be low, thus slightly increasing the angle of incidence in the left wing and decreasing angle of incidence in the right wing, thus causing same to be heavy when plane is in flight. This condition can be remedied by slacking and taking up on the various wires above mentioned.

CHAPTER XXI

Care and Preservation of Aircraft in Storage

Aircraft in storage in crates are preserved by removing the top and one side of all boxes; the windows and doors of buildings should be kept open at least six hours per day every day except Sundays, holidays and in inclement weather, and the building be kept free of rats or mice.

Planes that are erected should only be stored when they are thoroughly clean in every respect, pontoons drained, handhole plates off, all control wires being well greased, load and lift and other strand wires being coated with lacquer or other preservatives. Remove any corroded spots on fittings by the use of a dull knife or scraper and touch up with red lead paint. Plane should be in perfect alignment, otherwise a condition that should be other than normal would become exaggerated. Propeller should be left installed and turned to a horizontal position, oil left in tanks. If plane is going to be stored for only a short period of time fill all gas tanks to capacity, but if stored for an indefinite period gasoline should be removed and all gas tanks filled with kerosene. The filling of tanks with kerosene *only applies to small type craft*, it being considered impractical to fill flying boat tanks of such large capacity with kerosene; in the case of flying boats empty all gas tanks. Empty tanks due to changes in temperature will set up precipitation, causing tanks to corrode in the interior and as gasoline evaporates very rapidly it will soon leave space for precipitation of moisture. Engines should be turned over once a week; buildings should be kept well aired daily for at least six hours except holidays, Sundays and in inclement weather. In addition to removing drain

plugs in flying boats the interior shall be carefully dried by wiping up any water that may lie in places that do not permit of drainage. High humidity appears to be the greatest enemy to erected aircraft in storage, and every effort should be made to keep buildings dry and well aired.

Where it is impractical to remove the top and side of an aeroplane crate, such as large type flying boats, an opening should be made in each end of crate about two feet square. On one end the opening should be made about one foot above the floor or bottom side and on the other end the opening should be made near the top side. This will permit of circulation of air. If crates are stored in a building that is heated in winter a pan of water should be placed inside the crate near the lower opening. If building is not heated, no water pan is necessary.

PARACHUTES IN STORAGE

Parachutes in storage should not be kept in containers or kept folded, but should be suspended in a vertical position from the roof trusses of hangar, with the peripheral cords downward. Groups of parachutes suspended thus are covered with cotton sheeting to keep off dust, dirt, etc. If building has not sufficient pitch to permit of parachutes being suspended as above described the peripheral cords may be coiled upon a table or other elevation, *but not upon the floor*, the fabric of parachutes to be suspended and covered as in the first instance.

CHAPTER XXII

Aircraft "Don't's"

1. Don't endeavor to improve the flying qualities of any flying machine by making some change in design or construction of same, you may either kill yourself or some other person by so doing; *remember*, the machine will do all it is supposed to do, if properly assembled and aligned and motor functioning properly; if you have some idea, submit it to the officer in charge who will see that it is given due consideration.

2. Don't set up so tight on load and lift wires that you buckle a strut, the maximum amount of resistance to compression offered by a strut is before being deflected and not afterwards, besides there is no occasion for same.

3. Don't put a seaplane or flying boat up for the night without removing drain plugs, and on week ends remove all hand hole plates from pontoons as well, in order to ventilate same. It is to be remembered that gasoline, oil, and water is injurious to varnish, as well as the glue and fabric placed between inner and outer layers of planking.

4. Don't put boat or plane in water until all drain plugs are in.

5. Don't use files on aircraft wires or fittings, nor emery cloth or sand paper.

6. Don't use cotton waste or any kind of waste for cleaning motor or plane. A small piece of waste may get caught on some working part of motor, or on a control wire, and cause same to jam at a pulley or where same passes through a Bowden fair lead; always use cheese cloth.

7. Don't use salt water soap, or any soap containing free alkali, on the fabric; it is injurious to the fabric coatings;

use castile soap always if possible. A little gasoline might be used to remove a considerable amount of grease, but care must be exercised because gasoline will remove the fabric coatings also.

8. Don't fly a machine with broken strands in any wires, the wires have either become broken through an undue strain, or through lack of care have been permitted to corrode, the latter case being invariably the case with load and lift wires, pontoon brace wires, etc. Control wires usually become broken or frayed where same passes around pulleys, and while the cable itself might not break, due to a small number of strands having parted, there exists the danger of further fraying in the air, thus causing cable to become jammed in pulley housing, and probably causing a plane to be wrecked as well as loss of life.

9. Don't attempt to fly until you have tried out controls. It is a very easy matter to get the control wires reversed when renewing same; *this has occurred* and will cause a flyer to nose in.

10. Don't attempt flight without ascertaining that there is sufficient gas, oil, and water, and that the pipes and their connections are tight.

11. Don't attempt flight in a machine that has had a hard landing and is apparently O.K., until same has been inspected for broken wires, distorted or broken fittings, alignment checked up. My reason for making the above statement is as follows: N-9 Seaplanes in particular, upon being overhauled have shown distorted and broken fittings where pontoon struts connect to fuselage. These same fittings have attached to them the fuselage brace wires that are located in the engine, gas tank, and forward cock-pit sections, and are also found broken or slack due to damaged fittings brought about by hard landing. In many cases no one knew of this particular condition, as machines were being over-

hauled on account of their general condition, long number of flying hours, etc. In this connection pilots are cautioned when entering a flying machine of the single tractor seaplane or land machine, to reach forward on both sides and feel the wires to see if they are reasonably taut both in engine, tank, and cock-pit sections; it will only take a few seconds, and eliminate what I believe to be the non-recovery of some pilots when in a left turn or spin.

Owing to the propeller torque or reaction, whereby the fuselage tends to revolve on its axis to the left, which is well within the control of the pilot under normal conditions, such is not believed to be the case if a hard landing has been made whereby the fittings on the right side of forward cock-pit were distorted or broken in a hard landing, thus slackening these wires perhaps only a small amount, but sufficient to cause a slight twist in the fuselage at that point, which is amplified more or less in the tail units, thus throwing the right side of horizontal stabilizer upwards and the left side downwards, thus tending to increase the lift on the right side and decrease lift on the left side. This condition is not very apt to be noticed unless machine is in such a position where same would be conspicuous, which is not the case when students or pilot may return from a flight in which numerous landings have been made, when another immediately takes his place, goes up, puts machine in right spin, recovers, then left spin and can never recover, and is invariably said to be lack of experience. This may be true in some cases, but from what has been set forth here it is fair to assume that such is not so in all cases.

12. Don't smoke in hangars, nor in any type of aircraft, whether on the water, ground, or in the air.

13. Don't run your motor at full speed, except when being tested out after installation in plane and then for only short intervals. This applies to machines on the beach and not in

flight, the results of same will not only overheat the valves and other engine parts, but excessive vibration set up thereby is not good for the machine as a whole.

14. Don't enter the rear part of the hull in an HS-1-L type of flying boat without removing the hand hole plates for ventilation and blowing in hull air taken from a compressed air line hose, or ventilated by means of a portable electric blower with canvas hose discharge. A person is liable to be overcome with gas fumes; this has happened and required cutting through the top of hull to rescue the man.

15. Don't keep oily or greasy rags lying around the hangars; they are liable to catch fire through spontaneous combustion.

16. Don't walk on the ribs of a wing. If you have to walk out on the wing for any purpose be sure and walk on the wing beam and be careful with your steps.

17. Don't fail to keep your control wires well lubricated and inspected where they pass around pulleys or through Bowden fair leads, also two control wires crossing should not rub against each other.

18. Don't fly with rips or tears in the fabric. Patch same, otherwise you run a risk of having a large section of fabric torn adrift while in flight, which may cause a serious accident.

19. Don't walk any and every place on the hull of a flying boat—the planking is of light material and will break through easily. Use the reinforced places that are provided for the purpose.

20. Don't stand on either side of a propeller in motion, as no one can tell when a propeller may fly apart, and observe great caution, if necessary to examine motor while running, otherwise you run a risk of being seriously or fatally injured if struck by a propeller.

21. Don't attempt to adjust or repair instruments, if same are not working properly. Report same to officer-in-charge,

who in turn will take the matter up with the Instrument Officer.

22. Don't allow your machine to become dirty and grease coated; it is absolutely essential to keep an airplane as clean as possible, thus avoiding catching fire, and the machine itself from deteriorating.

23. Don't fill a gas tank without first having funnel in contact with tank and hose fitting in contact with funnel otherwise an explosion is liable to take place, being caused by a static spark. Stop flow of gas before removing hose or funnel.

24. Don't attempt to correct the tail heaviness of a machine, but report same to the officer-in-charge who will have someone who understands the reason for same take care of it. (Proper method described elsewhere in this book, under alignment of Aircraft.)

25. Don't attempt to correct right or left wing heaviness by giving the aileron a droop on the low wing when the other aileron is neutral. (Proper method described elsewhere, under Alignment of Aircraft.)

26. Don't fail to know and see that all turnbuckles are safety-wired on your machine.

27. Don't leave off a cotter pin because you might have to walk the length of the hangar to get one.

28. Don't keep leaky or half-filled Pyrenes on the machine; remember, when you need them you need them badly.

29. Don't kick on being furnished galvanized iron wire for turnbuckle safety wiring—it is really stronger than copper wire.

30. Don't use a turnbuckle on any wire that shows by table to have a less breaking strength than the wire or cable itself.

31. Don't substitute a smaller wire for one being renewed.

32. Don't use a short barrel turnbuckle on a long wire

because the table shows it to be as strong as the wire; there are both short and long turnbuckles of the same strength, and long wires require long turnbuckles.

33. Don't use a clevis pin of too small a diameter on a shackle; always use the largest clevis pin that you can get to go through holes in shackles and you can't go wrong.

34. Don't ream out holes in fittings or shackles in order to get a clevis pin or bolt to go through—you thereby weaken same if you do.

35. Don't bend the tangs on an aircraft fitting to bring same to proper angle. If you should be replacing a damaged fitting, and the tangs on the new one are not at the proper angle, get another, as it evidently is faulty in design; bending fittings cold tends to fracture the metal.

36. Don't put screws in any part of an aircraft whatsoever, without first boring a hole slightly smaller than the screw itself; this applies to the very small screws used on cap strips where same are fastened to the front and rear wing spars, as well as all others.

37. Don't drive screws in with a hatchet, hammer, or any other implement—always use a screw driver.

38. Don't use wood that shows worm holes in any part of an aircraft.

39. Don't allow the fittings to become corroded on the machine; remove the first signs of corrosion with a dull pocket knife or a small scraper, and touch up same with red lead paint.

40. Don't allow load and lift wires, pontoon brace, drift, wing-tip, float, non-skid, rudder, elevator, stabilizer, aileron brace, control wires, or any exposed wires to become corroded; this can be prevented by the use of Universal lubricant, or any other wire dope provided for the purpose.

41. Don't fail to examine frequently the control wires that pass through the hulls of flying boats or fuselages in seaplanes; they may be rubbing against each other.

42. Don't attempt to correct the error if a machine is out of alignment in some one place, unless you know just what to do, otherwise you are sure to make a bad matter worse.

43. Don't use Bowden fairlead cable of a length whereby the wire passing through same is always concealed, but where used the travel of the wire should be sufficient to expose same.

44. Don't go in the air in any airplane that is going to fly over water without a life preserver. Many have lost their lives through the lack of same. In other words, the life preserver should be worn and not used as a seat or back rest.

CHAPTER XXIII

The Air Speed Meter

FUNCTIONS

The function of the air speed meter is to register the speed of the plane through the air, without reference to its speed over the ground.

Example: A wind is blowing with a velocity of 20 miles per hour. We have a plane whose maximum speed is known to be 60 miles per hour. If we fly straight into this wind, we have 60 minus 20 or 40 miles per hour for our ground speed. We turn and fly with the same wind. Then we have 60 plus 20 or 80 miles per hour for our ground speed.

Our air speed in both cases will have remained at 60 miles per hour, provided the plane has been kept on a level keel and the R.P.M. of the motor has been constant. Of what advantage is this knowledge to the pilot?

The airplane derives its lift from the air passing over its inclined surfaces. The speed necessary to obtain this lift is called "flying speed." A loss of this speed is known as a stall, or "Compte de Vitesse" as the French say, and results in a loss of control over the plane. The control surfaces will not respond, due to the resultant decrease in air pressure on them and the plane usually falls into a tail spin.

"Solo" students, due to a lack of experience, are often unable to sense a loss of speed while in flight and are particularly liable to this sort of trouble.

The air speed meter shows the pilot at all times whether or not a safe margin of flying speed is being maintained, regardless of the direction of movement of the body of air through which he is flying. It forewarns the pilot when the

plane is approaching a stall; shows correct speed when gliding, and when diving the plane; enables him to know when the highest velocity has been attained, from which he can make a safe recovery—this varying with the structural strength of different types of planes.

The air speed meter has been found to be particularly indispensable on the larger types of aircraft such as the Handley-Page land planes or the N·C types of flying boats where the mass is so great that the pilot can not depend upon "feel" of the craft.

DESCRIPTION

The air speed meter assembly is composed of three main parts:

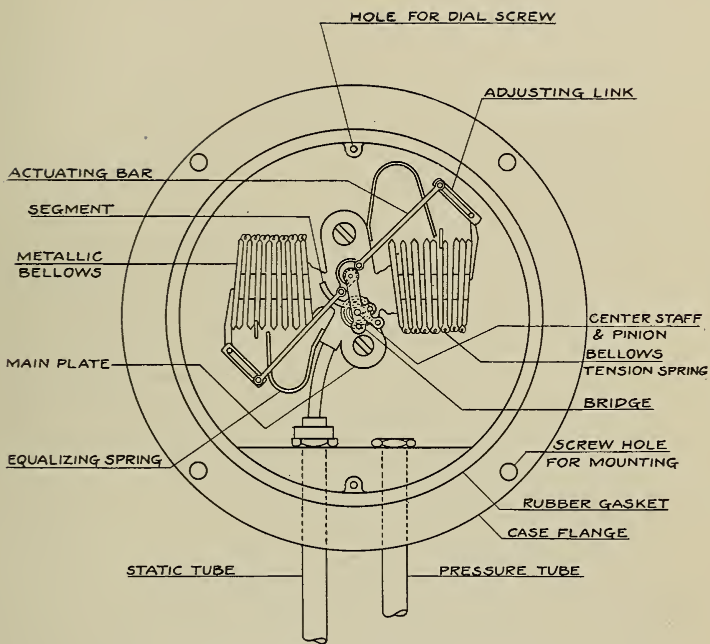
The "nozzle," or "venturi tube"

The "gauge" proper

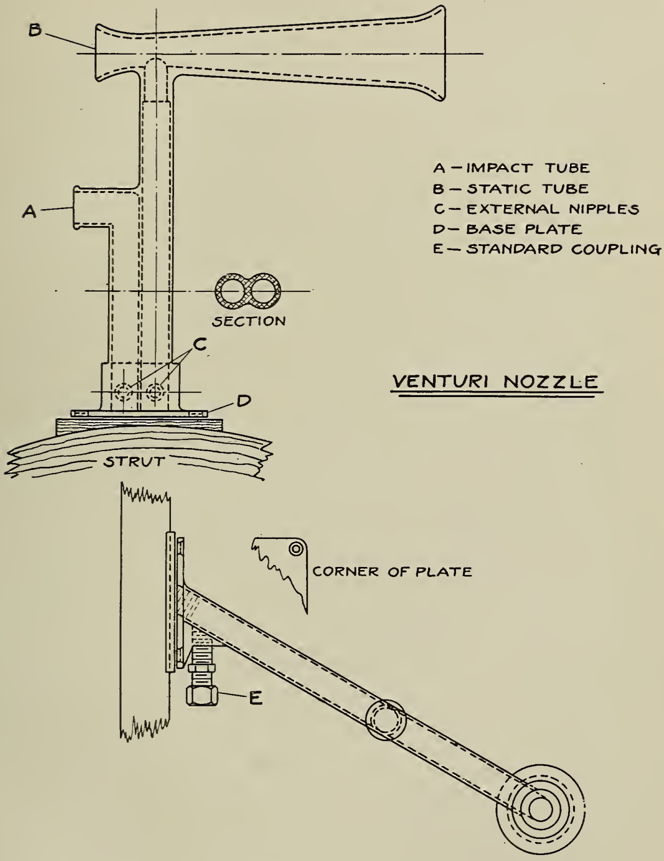
The copper tubing and the flexible connections.

We will first give our attention to the gauge, which is an instrument of the diaphragm type. An air tight cylindrical case, usuall of aluminum, contains the mechanism. Flexible metallic bellows of very light construction and of sensitive action are directly connected to the "*static*" tube leading from the case to the "*static*" tube of the nozzle. A suction head is produced by the air stream passing through the "*static*" tube of the nozzle which acts upon the *inside* of the bellows or diaphragm. A pressure head is produced in the "*impact*" chamber of the nozzle by the "*impact*" of the air stream which transmitted through the pressure tube to the inside of the air tight case acts upon the *outside* of the bellows.

The elasticity of the bellows resists the combined action of the two atmospheres, *pressure* and *suction,* and the result is a distension of the diaphragm. This slight action is multiplied through levers, and transmitted through a segment to a



AIR SPEED METER ASSEMBLY


B
A
A — IMPACT TUBE
B — STATIC TUBE
C — EXTERNAL NIPPLES
D — BASE PLATE
E — STANDARD COUPLING
SECTION
C
D
STRUT
VENTURI NOZZLE
CORNER OF PLATE
E

pinion which carries the hand as shown in plate 2 of the illustration.

A double hairspring provides a return action for the hand. Dials for air speed meters are graduated in knots or nautical miles per hour usually from 30 to 140 knots according to the speed of the plane for which it was designed. Both hand and dial are suitably illuminated by the use of luminous paint.

A rubber gasket provides an air tight cushion for the glass which is of double thickness and is held securely in position by a threaded bezel. An extended flange is drilled with holes for screws for securing the instrument in place on the instrument board.

THE "NOZZLE" OR "VENTURI TUBE"

By consulting plate 3 of our illustration, we see that the nozzle consists of a single throat "venturi tube" and a small impact tube both of which, when installed on the plane, point into the wind at the normal angle of flight.

The prevailing practice has been to manufacture these tubes of aluminum but due to the chemical action in the tube caused by salt water spray in the case of seaplanes and other hydro-aircraft, aluminum is being discontinued in favor of copper. Any deposit or roughness in the tube will affect the readings materially. A variation of $\frac{5}{1000}$ of an inch in the bore of the tube being sufficient to cause an error of 2 to 4 knots in the reading on the dial.

The two tubes form one casting with a flanged base for attaching to the strut. Two external nipples serve to connect the tubes leading from the nozzle to the pressure gauge tube.

The characteristics of the tube are such that at a speed of 100 knots per hour, the difference in pressure between "P" and "S" is 42 inches of water. At other speeds the variation of the pressure head is directly proportional to the square of the velocity.

TUBES AND CONNECTIONS

The tubes for connecting the nozzle to the air speed meter are of copper $\frac{1}{4}$ inch in diameter. The couplings are made by means of heavy rubber tubing carefully shellacked to insure against any possible leakage. One is usually placed at the lowest point in the line to facilitate drainage should any moisture condense in the tubes.

INSTALLATION

The mounting of the air speed meter differs slightly with different types of planes, but in every case the nozzle is so placed that it will not be affected by the air stream from the propeller or by the eddy currents set up by some part of the structure.

On hydro-aircraft the nozzle is mounted well up on the strut to avoid as much spray as possible in "taking off" and landing. Plate 2 shows clearly the conventional position for mounting the nozzle on the forward strut of the outer wing section.

Great care should be exercised when securing the nozzle to the strut, to avoid cutting away or drilling holes in the wood, or any other alterations that could possibly lower the factor of safety of the strut. It will be noticed that the nozzle slopes downward from its base at an angle to prevent rain or other moisture from entering the tubes. All connections between the nozzle and air speed meter must be air tight and there must be no sharp bends nor kinks in the copper tubing.

The location of the instrument on the instrument board in the cockpit of the machine is relatively of little importance, the principal object being to have it easily visible to the pilot.

TROUBLES

When an air speed meter fails to register correctly, it is usually due to one of the following causes as given below with the corrections for each:

(a) Air leak at connections
(b) Split in copper tubing
(c) Hole in case of instrument from corrosion or other cause
(d) Crack in glass
(e) Leak at rubber gasket due to hardening or deterioration.
(f) Hand loose on pinion.
(g) Water collected in tubes.
(h) Nozzle set at an angle to the line of flight.

THE AIR SPEED METER

Corrections:

(a) Renew rubber connections and shellac carefully.
(b) Replace tubing or solder if convenient.
(c) Remove mechanism from case, ream out hole and fit with plug of same material as the case.
(d) Replace glass.
(e) Renew rubber gasket if possible or coat with ordinary tire cement and replace glass in position.
(f) Close hole slightly, using a ball-faced punch in the staking tool.
(g) Drain the line thoroughly at the lowest point by removing connections.
(h) Raise the tail of the plane until the wings are at the angle of normal flight, then check position of the nozzle to see that it is just horizontal.

CALIBRATION

As before stated, the markings of a dial of an air speed meter in knots are equivalent to the indication on that gauge of a certain pressure which corresponds to the speed of air by the nozzle. Therefore, in order to test the gauge, a manometer is necessary and the manometer and the gauge connected in parallel. A hand bulb is used to produce the necessary pressure. A scale can be had for use in connection with manometer, reading correctly in knots and pressures in inches of water.

By simply increasing the pressure, it can be determined whether or not the gauge reading corresponds to the reading of the water manometer which is the standard. Attention is called to the fact that the gauge must be connected on the tube marked "pressure," or it will read in a reversed direction and be injured.

The instrument shall always be handled with the utmost care as shocks are detrimental and under no condition should the instrument be blown into.

In view of the cost of the apparatus needed and the experience necessary for re-calibration of air speed meters, we recommend that the instrument be sent to an aero laboratory to insure the best results.

TEST OF THE NOZZLE

The nozzle is tested by taking the plane over a measured course, it having been previously determined that the gauge is correct and all connections tight. Should the reading then be incorrect, the position of the nozzle with respect to the plane should be checked, and if everything is found to be in order the nozzle should be deemed defective and should be returned to the makers.

A nozzle will be considered satisfactory if the reading of the air speed meter corresponds to the actual speed over a measured course within 2 per cent. To obtain very accurate timing a still day should be chosen for speed trials. If the wind is blowing, the usual methods of allowing for drift should be exercised, but it is reasonable to expect that the air speed meter may not check quite so closely as on a test under more favorable conditions.

CHAPTER XXIV

The Altimeter

FUNCTIONS

The altimeter is an instrument mounted on an aircraft to show *continuously* its height above the surface of the earth from the point from which it started. This point must be kept in mind when flying near mountains. When flying through clouds or a heavy fog at low altitudes, the altimeter is a decided necessity.

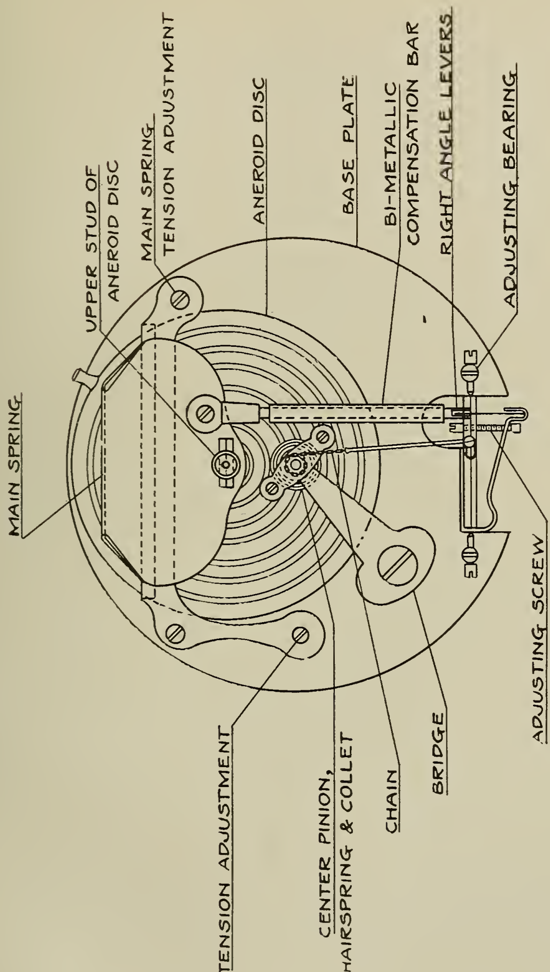
There is considerable lag in even the most improved types of altimeters, while climbing this lag is of little concern as the rate of ascent is comparatively slow, but when gliding down the loss of altitude is comparatively rapid and the instrument may not register this loss as rapidly as it actually takes place. Accidents have occurred from this cause alone when landing in heavy fogs.

The altimeter is always set to register zero at the ground level of the starting point.

DESCRIPTION

A cylindrical case of aluminum similar to the case of the air speed meter contains the mechanism; it has an air vent in the case so that the atmospheric pressure at various altitudes inside and outside the case will be equalized.

The mechanism consists of a corrugated, hollow disk made of resilient metal from which the air has been exhausted, commonly known as an aneroid disk. Two studs are fastened in the center of this disk on opposite sides. The lower stud is secured to the base plate, the upper to a stiff curved



ALTIMETER

PLAN VIEW

spring. The disk is thus held in tension between the base plate and the mainspring.

A bimetallic compensating bar connects the spring to a set of right angle multiplying levers as shown in plate 3. The final transmission of movement to the hand is obtained by means of a chain such as may be found in English watches of the "fusee" type. On older types of altimeters, horse hair or fine catgut is sometimes used in place of a chain but both are unsatisfactory due to the effect of moisture on them.

A collet on the center staff acts as a drum for the rolling and unrolling of the chain, a hairspring provides a return action for the hand.

The dial is secured to a movable milled bezel which is turned when setting the altimeter to zero before starting on a flight. Thus the hand remains stationary and the zero on the dial is moved to coincide with the hand. A locking device holds the bezel securely in place when set and prevents the vibration of the plane from turning the dial in error.

Dials for altimeters are calibrated in feet from zero to the capacity of the instrument in hundreds and thousands of feet. Various types range from 10,000 to 20,000 feet maximum depending on the work for which they are intended. Numerals and hands are illuminated on modern types by use of luminous paint.

PRINCIPLES INVOLVED

For every given altitude there is a corresponding decrease in atmospheric pressure.

The aneroid disk containing a partial vacuum is partially collapsed against the tension of the mainspring by the normal atmospheric pressure at sea level. As the aircraft gains altitude, the decreasing atmospheric pressure allows the disk

to expand in like proportion. This slight action is transmitted from the mainspring through the compensating bar to the multiplying lever, through chain to center staff which carries the hand. In descending, the action is reversed.

It is well to bear in mind that pressure *decreases* as altitude *increases*, in spite of the fact that the reading in feet is higher. There are other conditions beside pressure which affect an altimeter; namely, temperature of the air, and vibration of the machine.

The altimeter is compensated for any change affecting the instrument itself, ranging from below 0 to over 100°, but no satisfactory way has yet been discovered for compensating for the changes in temperature of the atmosphere itself.

TROUBLES

Altimeter troubles can easily be traced to one of the following causes:

(a) Plugged air vent
(b) Loose hand
(c) Bent center staff
(d) Chain rusted
(e) Hair spring rusted
(f) Bearings gummed
(g) Diaphragm fatigued
(h) Off calibration

Corrections:

(a) Remove hand and dial, and open vent with a steel broach using care not to enlarge it beyond its original diameter. Never insert broach with out first having removed the dial in order to avoid injury to any part of the mechanism. Make sure that no particle of foreign substance from broaching remains in the case.

(b) Remove hand with proper hand remover and close brass cup in center on a staking tool. Avoid touching luminous paint with the fingers or cracking it during the operation.

(c) Release chain from lever and remove the bridge supporting the center staff, hairspring and collet. Remove the brass chain, collet and the hairspring; place center staff in a lathe between centers and true. It will seldom be found necessary to anneal the staff during this operation.

(d) If badly rusted, replacement with a new chain is advised, otherwise a thorough cleaning and oiling may be sufficient.

(e) Renewal is always advised in cases of rusty hairsprings.

(f) A thorough cleaning and oiling, using the same general methods as used in cleaning French clocks, will remove this trouble.

(g) In this case the diaphragm has lost its elasticity and a replacement is the only solution of the difficulty.

(h) The apparatus necessary for the calibration of an altimeter is simply a bell jar and suction pump as shown in plate 4.

An altimeter whose calibration is known to be correct is placed under the bell-jar with the instrument to be tested; the air is gradually exhausted from the bell-jar by means of the suction pump and the difference in readings noted. Adjustment is obtained by turning the adjusting screw on the right angle levers which simply increases or decreases the motion, as the case may be.

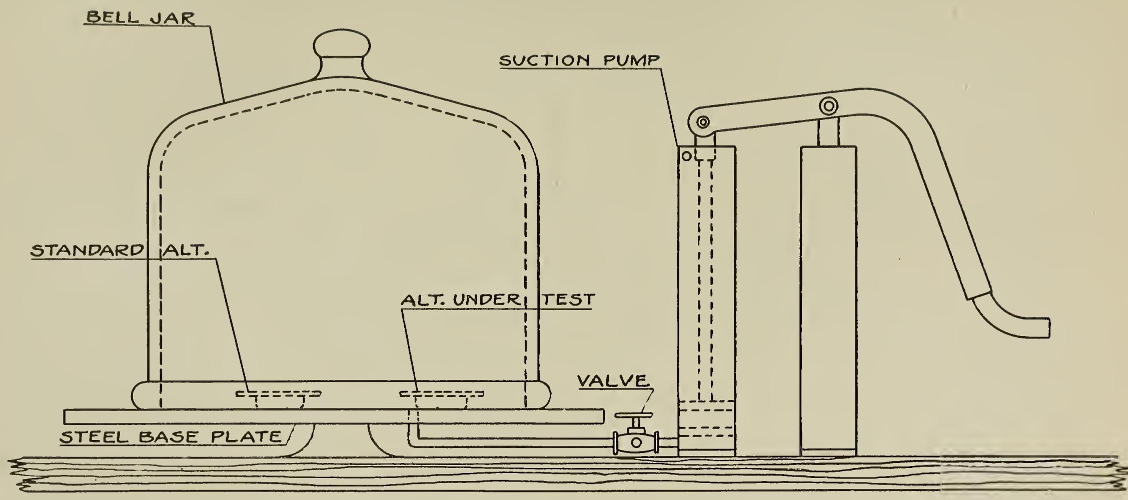
Due to the fact that the interior of the altimeter case is connected to the outer air via the vent, we find it subject to more or less trouble from corrosion and rust in the mechanism

and consequently in need of frequent attention. This is particularly true when the instrument is installed on water craft.

The altimeter is mounted in a hole on the instrument board according to the blueprints of the particular type of the machine for which it is intended.

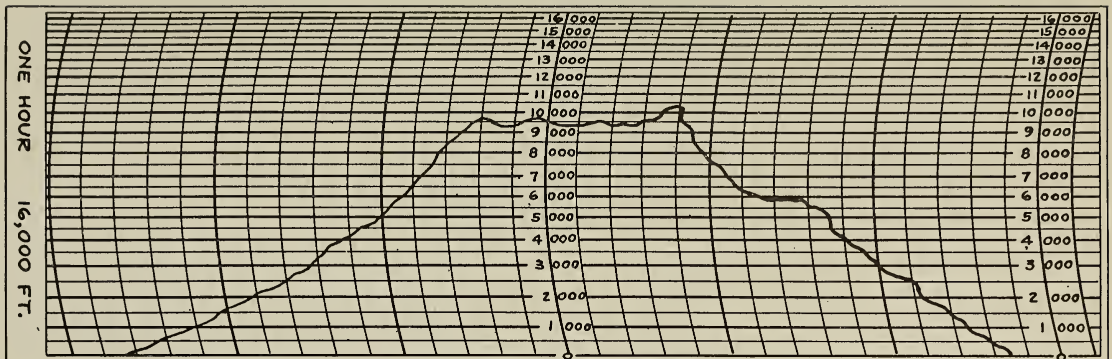
Care should always be used to keep the small vent at the base of the instrument clear. It has been found advantageous in some types of planes to support the altimeter in a ring of live rubber which of course absorbs a great deal of vibration and insulates the instrument to some extent from shocks.

The latest types of altimeters have a diameter of $3\frac{1}{2}$ inches and in some cases have the capacity up to 30,000 feet, which will be increased as the "ceiling" of aircraft grows higher.



TESTING APPARATUS

(ALTIMETERS)



RECORDING BAROGRAPH CHART

CHAPTER XXV

The Recording Barograph

The recording barograph is a member of the altimeter family, recording graphically on a chart the course taken by an aircraft in flight, in time elapsed and in altitude made.

The charts used for these records are graduated vertically in feet, and horizontally in hours and minutes.

By means of the recording barograph, the pilot, after the completion of the flight, may follow his up and down course through the air, know the time consumed in reaching any altitude he may have made, and also make comparisons of climbing and gliding speeds. He can also note his exact altitude for any minute of his flight. A great deal of interesting and instructive information may be deducted from a finished chart. Plate 5 shows clearly a chart with the contour of a rather interesting aerial voyage.

The barograph is sometimes used to check the skill of the pupil in carrying out orders to fly over a given course at a given altitude. A steady climb is indicated by a steady line but if the line on the chart is full of jerks or sharp angles, it shows that the rate of climb was uneven.

Official altitude tests are always verified by the use of a sealed recording barograph.

DESCRIPTION

The mechanism consists of three principal parts all mounted on a common base; the clock work and chart drum, the tracing pen, the aneroid and connecting levers.

In the best practice, the clock work is contained in the

drum which revolves around it, and the chart is secured tightly around the cylinder by suitable clips or lugs. As the drum revolves the pen draws an actual curve of altitude against time on the chart. The pen which is located at the end of a long arm or spring is similar to the point of a drafting pen and has a recess or well for holding the special glycerine ink which is furnished with the instrument. An adjustable steady post serves to hold the pen against the paper chart at an even tension. The arm holding the pen is directly connected to the fulcrum bar of the right angle lever which is in turn connected to the aneroid.

On account of the action required to produce the motion of the pen against the revolving chart, two or more aneroid disks are used, held in tension between the base plate and spring much the same as in the altimeter, also a more sensitive action is obtained by the use of the additional disks.

The bearings of the levers and fulcrum bars are hardened and pointed pivots, supported by suitable "Vee" bearings which are adjustable. Accurate fitting at these points is imperative as any loss of motion here would greatly impair the action between the aneroid and the point of the pen.

A hinged cover protects the entire mechanism and is provided with means for locking and sealing as may be required for tests. A small observation window directly over the chart enables the pilot to take readings while in flight.

The pocket barograph is simply a smaller and more compact edition of the larger one. The principal difference being in the means for holding the chart, which travels under tension over two rollers instead of revolving on a single drum.

TROUBLES

The usual troubles in their order are given below:

(a) Improper consistency of the ink.
(b) Failure of pen to feed.
(c) Roughing of surface of the chart.
(d) Error in altitude reading.
(e) Error in time reading.
(f) Stoppages.

Corrections.

(a) A special ink is required that must be of proper viscosity, neither too thick, which results in a failure to flow; nor too thin which means a smeared chart and empty pen. Ink should be tested in an ordinary ruling pen, such as draftsmen use before filling the pen on the Barograph.

(b) Failure of the pen to feed is usually due to one of two things, the points set too close or the steady post usually results in a failure to feed at high altitudes, as the angle of error increases toward the top of the steady post. Straighten post until pen touches at all points from bottom to top.

(c) Usually two causes; pen point too sharp or burred, chart paper of poor quality.

Smooth point by careful dressing on fine oil stone.

Renew the supply of charts and see that paper is of good quality, smooth surface and firm.

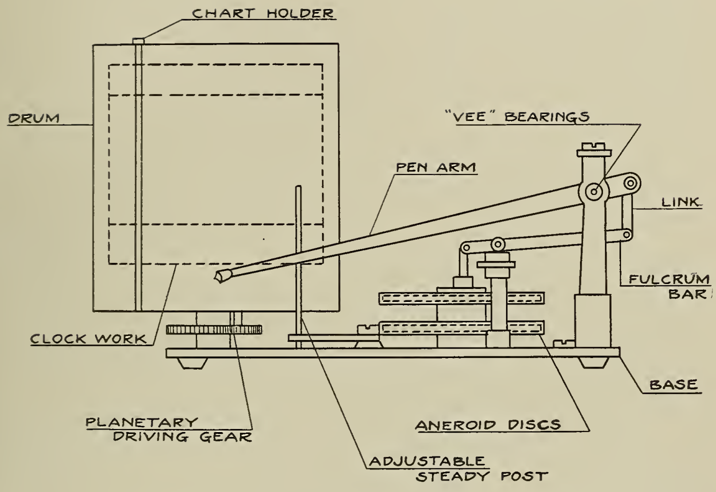
(d) Check calibration by test under bell-jar using same methods as for calibrating the altimeter.

Inspect all bearings for loss of motion. Make sure the pen is operating smoothly in the vertical.

(e) Inspect movement of clock work for possible causes of intermitting stoppage. See that chart fits drum closely and does not slip. Clock work must be regulated correctly for time keeping.

(f) Inspect driving gears between clock work and drum for possible obstructions such as bits of paper or other foreign matter as might cause a stoppage. Make sure that clock is in first class running condition.

A careful study of the plate 6 should give the reader a thorough knowledge of the instrument.



RECORDING BAROGRAPH

CHAPTER XXVI

The Tachometer

THE TACHOMETER OR REVOLUTION COUNTER

One of the most accurate and dependable checks on engine performance for the airplane is obtained by means of the tachometer which shows on a dial the revolutions per minute of the engine.

The pilot may be an expert on aircraft engines and be able to tell from the sound of an engine a great deal about its performance, but after a short time in the air with the motor running "full out" the hearing is more or less impaired by the changing of atmospheric pressure and the roaring of the exhaust so that in the end the tachometer is the real source of information.

The tachometer is driven off the crankshaft, the camshaft, or pump shaft of the engine depending on the type. A suitable adapter is used and a correct gear ratio interposed between the shaft on the engine and the flexible shaft of the indicator. The dial is calibrated according to the speed at which the engine runs, usually from 200 R. P. M. to 2400 R. P. M. which covers the field of aircraft engines.

Some tachometers have a recording device and much like those used on speedometers for motor cars, but on later types this has been discontinued, as the limited use for a device of this kind did not warrant its cost.

DESCRIPTION

The tachometer unit may be divided into three parts: the tachometer head, the flexible drive shaft, and the adapter.

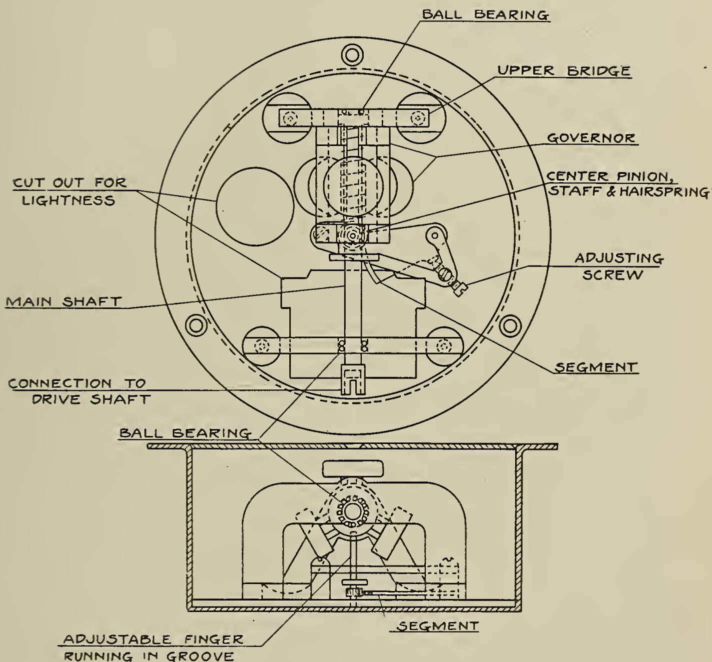
The usual adapter consists of a set of double gears inclosed in a swivel housing, of proper gear ratio for the engine and tachometer speeds. (See plate 7.) The flexible shaft is similar to those used in automobile practice for driving speedometers.

We shall be chiefly concerned with the tachometer head and a careful study of the text and plates should make the reader entirely familiar with it. The mechanism is inclosed in a case of $4\frac{1}{2}$ inches in diameter, usually of pressed steel as the working parts of this instrument are subjected to more strain and vibration than any other instrument on the airplane. A number of different types are manufactured, but the centrifugal type using a flyball governor seems to predominate. (See plate 7.)

A ring governor was used in early efforts by some European makers consisting of a ring pivoted at the center and held in a plane inclined to a horizontal by a spring action. Upon rotating, centrifugal force would tend to make it assume a horizontal position. The objection to this type being that in starting and at low speeds the governor was badly out of running balance causing excessive vibration and surging.

Electric types are still in use by the French but owing to cost, weight and the difficulty of keeping them calibrated while in service they have not proved generally satisfactory.

A chronometric tachometer of the escapement type is now being manufactured in this country and is extremely accurate. Errors are not cumulative as in centrifugal types due to automatic correction every half second. A fine tooth gear driven from the main shaft at a speed proportional to the R. P. M. of the engine engages a rack or counter which is in turn connected to the escapement mechanism. The function of the escapement is to hold the counter in connection with the driving pinion for a definite period usually one-half second. This period of time is constant regardless of


BALL BEARING
UPPER BRIDGE
GOVERNOR
CUT OUT FOR
LIGHTNESS
CENTER PINION,
STAFF & HAIRSPRING
ADJUSTING
SCREW
MAIN SHAFT
SEGMENT
CONNECTION TO
DRIVE SHAFT
BALL BEARING
SEGMENT
ADJUSTABLE FINGER
RUNNING IN GROOVE

TACHOMETER

the R. P. M. of the driving pinion. The angle through which the gear is rotated in the half second of time it is in mesh is proportional to the speed of the engine. The motion of the counter is transmitted through levers into a proportional angular rotation of the hand on the dial. Power for driving the escapement is derived from a mainspring which is wound automatically and contained in a barrel similar to those found in watches. The inner end of the spring is connected to an arbor, the outer end being free to rotate within the barrel. When sufficient speed has been attained, the free end of the spring will slip around the inside of the barrel the speed of which will remain practically constant, the pressure exerted by the spring on the inside of the barrel being sufficient to drive the escapement.

The one possible objection to this type is the fact that it does not register the speed variation at the instant it occurs, it being necessary to wait a full counting period before any variation is shown. Thus, the hand of the instrument appears to have a somewhat erratic and jerky action during the periods of change in the R. P. M. of the motor.

We will now take up in detail the construction of the centrifugal type. A heavy brass plate forms a base on which is mounted two bridges forming supports for the ball-bearings upon which the main shaft rotates. A governor of the fly-ball type is mounted on the shaft and acts directly against the tension of a coil spring. A flexible coupling at the lower end of the shaft provides a means of connection to the flexible driving shaft.

A grooved ring integral with the lower part of the governor transmits the action of the governor through a hardened steel finger riding in this groove to a pivoted bar carrying a segment. The segment engages a pinion on the center staff which carries the hand. A hairspring provides the return

action for the hand. Two adjusting screws limit the motion of the segment bar and make calibration of the instrument comparatively simple.

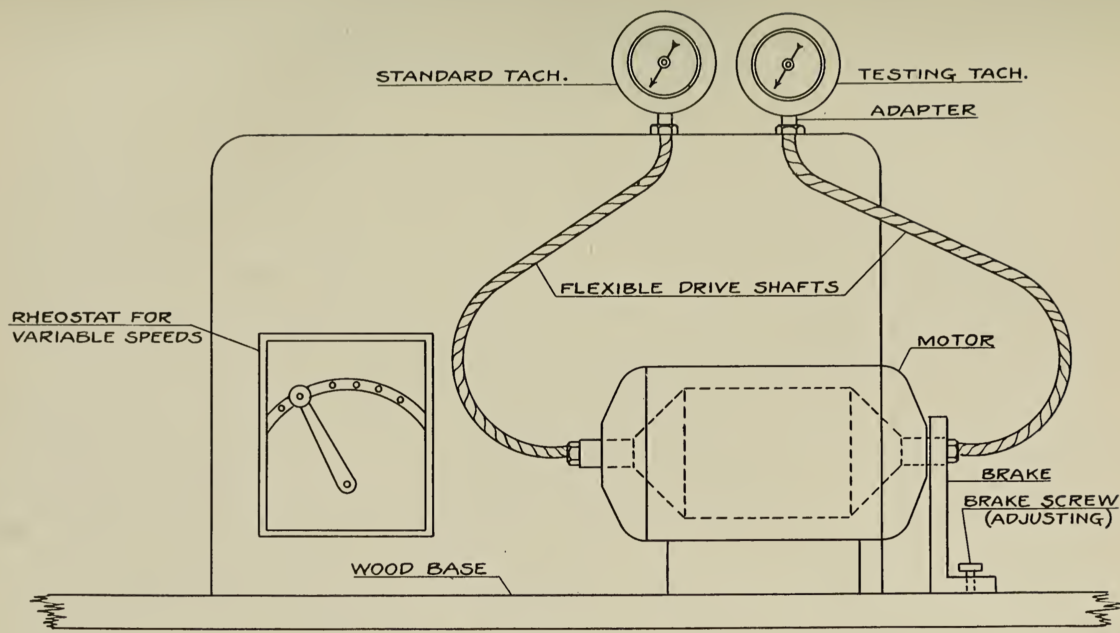
TROUBLES

(a) Broken connections in drive shaft.
(b) Loose hand.
(c) Surging.
(d) Vibrating of hand.
(e) Sticking of hand.
(f) Off calibration.

Corrections:

(a) Replace pins which may be sheared off.
(b) Use same method for tightening as given for altimeter hand.
(c) Surging is caused by the governor being out of balance. A careful checking of all its component parts will usually reveal a bent member as the cause of the trouble.
(d) Insufficient tension of the hairspring. Lack of lubrication on moving parts.
(e) Burrs on moving parts or oil which has gummed.
(f) The apparatus necessary for calibrating tachometers is shown in plate 8, and consists of an electric motor equipped with a resistance for variable speeds and a coupling for tachometer drive shaft.

The tachometer to be tested may be checked against another tachometer whose calibration is known to be correct or by means of an ordinary speed counter and stop watch.



TESTING APPARATUS
(TACHOMETER)

The corrections as before mentioned are made by means of two adjusting screws on the segment arm of the instrument.

Dials and hands on the later models are luminous and a heavy threaded bezel holding the glass completes the case assembly.

CHAPTER XXVII

The Aero Compass

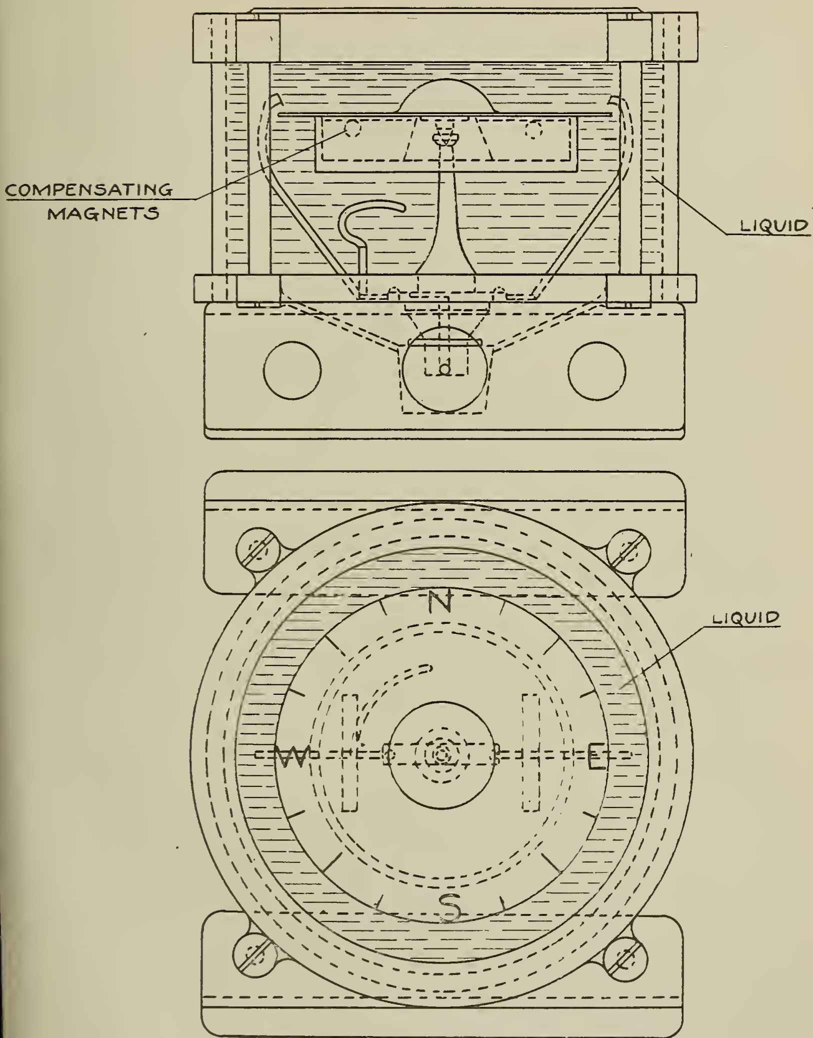
With the development of aircraft having a large radius of action has grown the demand for instruments for aerial navigation and the most important of these is the aero compass. (Although the gyro compass is in many respects ideal, up to the present time its weight and bulk have precluded its use for aerial work).

The compass now in general use on aircraft, and the compass we will study, is of the vertical magnetic type. As shown in plate 9, the aero compass consists of a heavy glass bowl mounted in a suitable frame work of some non-magnetic material, which is provided with brackets for installation in the plane.

The compass proper is insulated from shocks and vibration by rubber pads or a cushion made of horse hair. The compass card is mounted on a jewel pivot and may be read either from the top or from the edge. The card floats in a mixture of alcohol and distilled water to damp vibration. The needles or bundle of needles is fastened to the under side of the compass card.

When not affected by local magnetic influences, the needle will point to magnetic north. On an airplane, there are, however, almost always other influences which distract the needle from magnetic north. This error is called deviation, and is corrected by the use of compensating magnets placed on the side or below the compass, running fore and aft and athwartship.

The main thing to realize about the compass is that as a navigating instrument it is worse than useless if not properly



AERO COMPASS

installed and compensated for the errors. This cannot be accomplished until it is well understood and appreciated how easily a compass may be affected. Every time the machine undergoes any changes such as motors, gas tanks, or other metal equipment, the compass must be compensated. A severe shock or a change from one latitude to another will often affect the deviation.

COMPENSATION

To compensate a compass in a machine, the following instructions should be carefully observed:

1. Be sure to have all the equipment aboard, such as tools, spare parts, or other metal bodies which are a part of the regular equipment of the planes.

2. By means of a standard compass establish a north and south line. Likewise establish an east and west line. These lines may be either on the ground or on a range.

3. Level the machine carefully and make sure there is no magnetic material in the vicinity.

4. Head the plane due north and note the arrow in the compass reading. Correct this error by inserting or removing, as the case may be, the necessary athwartship magnets.

5. Head the plane due east and correct as before using the fore and aft magnets. These correcting magnets are usually small bars of soft iron heavily magnetized and are supplied by the manufacturers for the compass.

The period of a compass should be from 14 to 18 seconds; that is the time it takes to make one complete oscillation. Suppose we draw the needle east by means of a magnet. Then remove the magnet quickly and start a stop watch as the needle passes north going west and stop the watch when it passes north going west, and stop the watch when it passes north going west for the second time. Another way is to

take one-half of an oscillation. Start the stop watch as the needle passes north going west and stop it as the needle passes north going east.

To determine whether a compass is over sensitive or sluggish, count the oscillation it makes before coming to a dead rest.

A common source of trouble arises from a bubble forming in the compass. To correct this, unscrew the vent plug and fill with a mixture of distilled water and alcohol, by means of a common dropper. Connected to the side of the bowl is an expansion chamber made of thin metal to allow for expansion of the liquid due to changes in temperature.

Sometimes vibration will cause a compass card to spin and this may be usually traced to a badly mounted card or damaged pivot.

Directive force is the horizontal component of the earth's magnetic attraction. When a compass is sluggish in getting back to north, it is said to lack directive force. This may be due to some inherent bad quality of the compass or the pivot and pivot bearing may be rough. In jewel bearings a cracked jewel is a frequent source of this trouble.

In the modern types of compasses the numerals of the cards are luminous and the liquid slightly tinted to emphasize the markings.

CHAPTER XXVIII

The Temperature Gauge

The distance type temperature gauge enables the pilot to read on a dial located on the instrument board the temperature in degrees Fahrenheit of the water in the cooling system and also of the lubricating oil in the sump of the engine. This gives a timely warning of over heating and its resultant injuries to the power plant.

Oil and water temperature gauges are identical and interchangeable, usual types reading from 100° to 212°F. Some later models, however, are designed to read as low as 32° although this type of instrument is more delicate and is not so reliable as the first type mentioned.

The instrument consists of three main parts:

(1) The bulb containing the liquid.
(2) The capillary, or tube connecting bulb to gauge
(3) The gauge proper.

There are two general types in use at the present time, the vapor pressure and the liquid filled. The bulb containing the liquid is made of steel having a high tensile strength in order to withstand the high pressure necessary. A special male bushing, or nut, is provided for the attachment of the tube to the radiator or to the engine base. The tube is made of heavy copper with a hole of very small diameter and all connections brazed.

The gauge as shown in plate 10, is much like an ordinary pressure gauge consisting of a light Bourden tube, suitable connecting levers to a segment and pinion which carries the hand as described in detail in the lecture on Pressure Gauges. The dial is illuminated by the use of luminous paint and is

calibrated in degrees Fahrenheit instead of in pounds per inch.

Having extracted all the air from the bulb capillary and Bourden tube in the instrument, ethyl ether is introduced into the bulb under a pressure of 400 and 500 pounds per square inch. The tube is then sealed up. Ether is liquid at room temperature. The bulb, therefore, contains liquid ether in contact with other vapor in the tube and spring. A definite pressure results for every given temperature independent of the volume of the container.

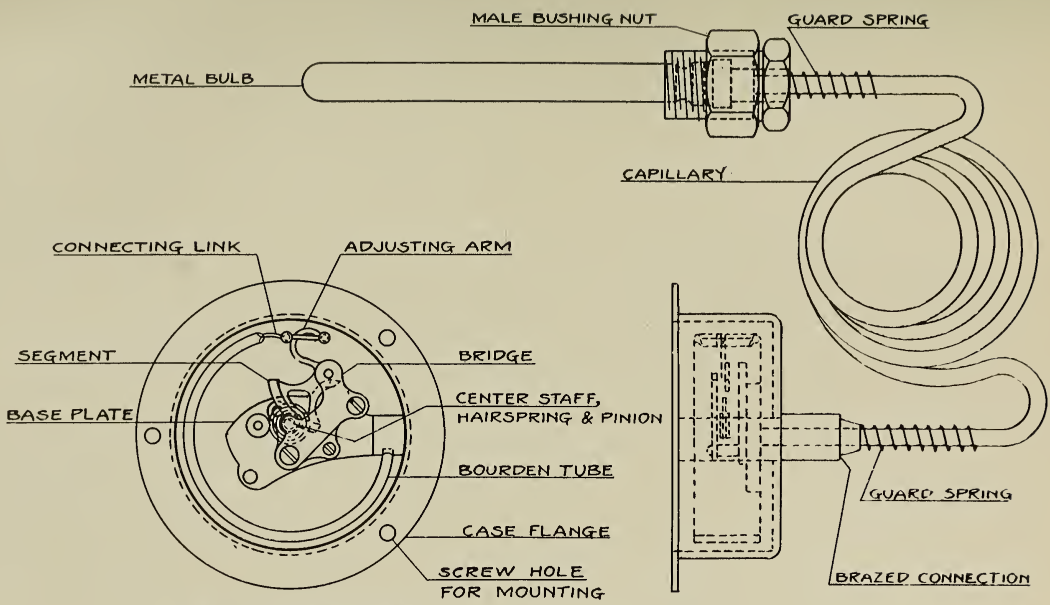
The higher the temperature the higher the pressure.

This pressure is an accurate measure of bulb temperature and is utilized to operate the Bourden tube of the pressure gauge. The pressure measured is of course a difference between vapor and atmospheric pressure. As the atmospheric pressure changes due to altitude, an error is introduced but excepting at extremely high altitudes this error is not sufficient to destroy the required accuracy of the instrument.

In instruments designed to record the lower range of temperatures, a liquid having a lower boiling point is employed. The two liquids now commonly used are sulphur dioxide and methyl chloride. There is some objection to the use of sulphur dioxide on the grounds that some impurity in the liquid might cause it to attack the metal with which it comes in contact. The liquid used must be of such a nature that it will not attack or amalgamate with the bulb and tubing materials. This precludes the use of mercury which is the standard in stationary practice.

THE LIQUID FILLED TYPE

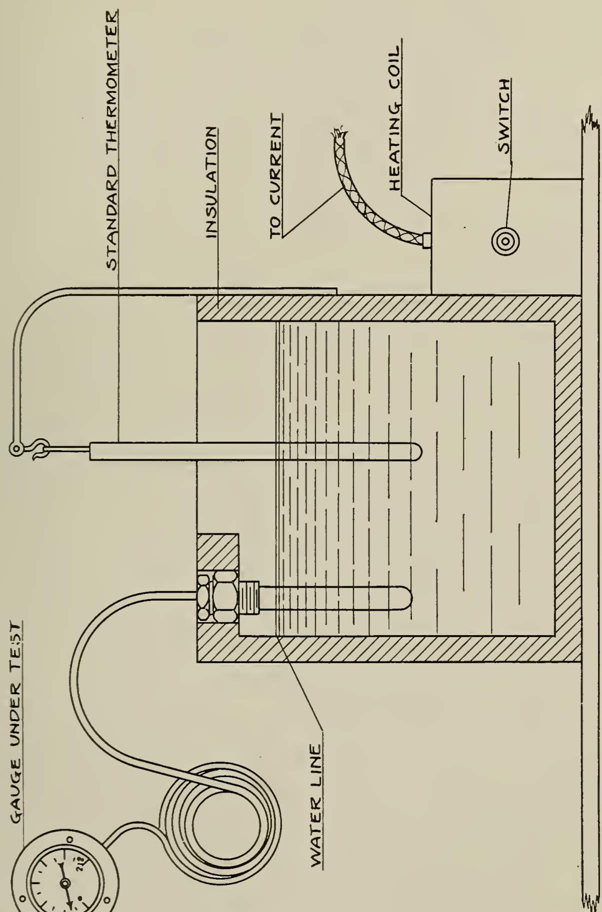
The liquid filled type registers from 32° to 212°F. The liquid is introduced into the bulb and capillary under pressure of 1000 pounds to the square inch. The capillary communicates with a coiled tube in the instrument, one end of which



PLAN VIEW OF GAUGE

TEMPERATURE GAUGE

PLATE 11



TESTING APPARATUS
(TEMPERATURE GAUGE)

is fixed while the other carries a compensating spring. The free end of the compensating spring carries the pointer. The increase of temperature in the bulb causes the liquid to expand and forces it into the coiled tube which tends to uncoil moving the pointer with it. In case the instrument is cooled considerably as at high altitudes the liquid in the coiled tube would contract and would cause the thermometer to read low, but the effect of the lower temperature on the compensating spring causes it to coil in the opposite direction, thus compensating for the error in the gauge so that it still indicates accurately the temperature in the bulb.

The diameter of the capillary is so small that the quantity of liquid contained, and therefore its effect on the reading, is negligible.

The greatest source of trouble in these gauges is the breaking of the tube. This is usually the result of careless handling by mechanics or from poor installation in the plane. As the refilling of these tubes is a most delicate operation requiring special equipment, we advise that in case of breakage they be returned to the manufacturer.

CALIBRATION

The apparatus for recalibrating temperature gauges as shown in plate 11 consists of an electrically heated bath and a standard mercury thermometer. The bulb of the instrument to be tested is submerged in the water which is gradually heated and the results in temperature checked against the standard thermometer.

Adjustment is obtained by means of a screw on the connecting arm of the segment which increases or decreases the motion of the pointer in relation to the spring action as may be needed to properly calibrate the gauge.

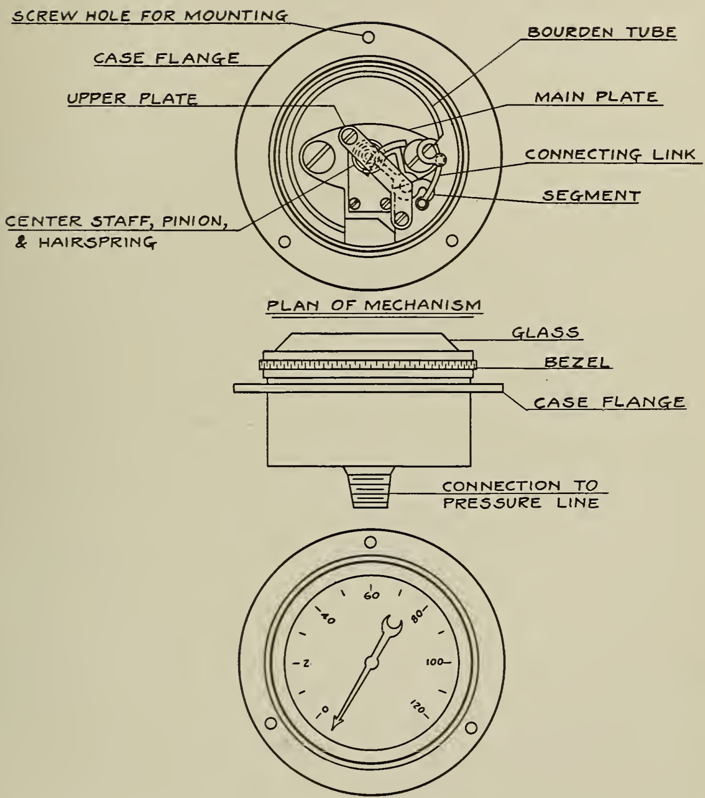
CHAPTER XXIX

The Pressure Gauge

The mechanism of the pressure gauge for either air or oil, is very simple and consists of only six parts, namely: A Bourden tube, connecting links, segment, pinion, center staff, and hair spring.

The Bourden tube is a flat, hollow, curved spring.

If the gauge is registering the oil pressure, it is directly connected to the oil line from oil pump. The oil goes into the Bourden tube and its pressure tends to straighten it out, the action being carried by the connecting links to the segment which is in mesh with the pinion gear on the center staff, causing it to turn. The registering needle is on the center staff. The hair spring serves to dampen vibration and assist in the return movement. See plate 12.



PRESSURE GAUGE

CHAPTER XXX

The Side Slip Indicator

The side-slip indicator is valuable as a means for checking the accuracy of the pilot's judgment in flying, and is particularly useful in the larger types of aircraft where the pilot's cabin is inclosed.

In an open machine the pilot can tell by the wind pressure on his cheek when he is making a faulty turn. Increased pressure on the right cheek on a right hand turn indicating an inward side-slip to the right, increased pressure on the left cheek under similar conditions would indicate an outward side-slip, or skid to the left.

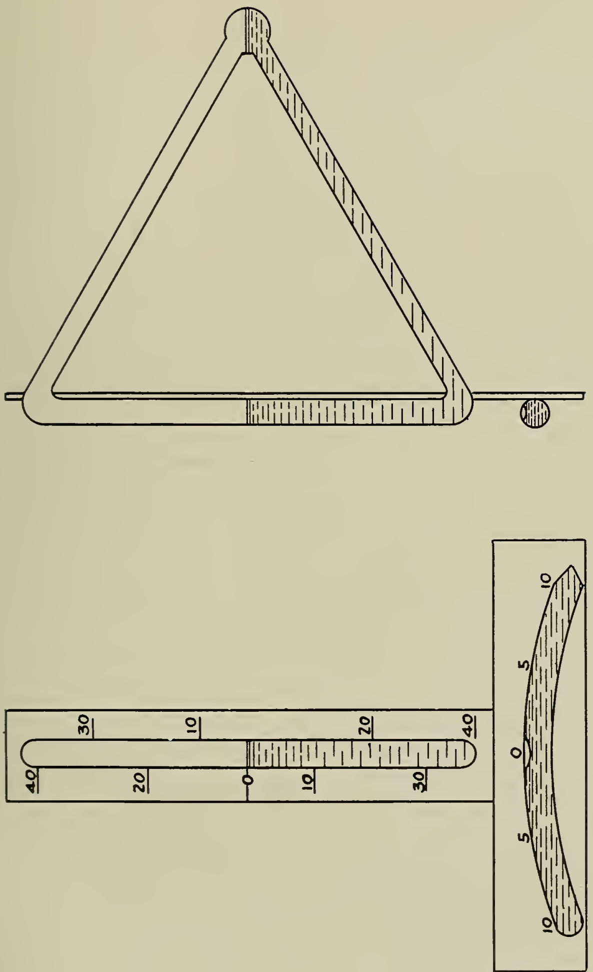
The instrument is of very simple construction consisting of a curved glass tube filled with a mixture of alcohol and distilled water to prevent freezing, and usually colored to aid visibility. The glass tube is mounted in a suitable holder as shown in plate 13, the holder being marked with an angular scale.

When the machine is flying level the bubble is in the center which is marked zero degrees. When a wing is lowered the bubble moves away from the low side, but in a properly made turn the resultant of the combined forces, gravity and centrifugal, is a line drawn directly through the center of the aircraft and the bubble will remain at zero degrees as the centrifugal force which tends to throw the liquid outward will have been neutralized by a proportional addition of gravity in banking the plane.

Practically no repairs can be made to this instrument, a broken tube necessitating a replacement.

Great care should be exercised when installing the instrument to have the aircraft level laterally and that the bubble be exactly in the center over zero degrees when the indicator is attached to the instrument board.

PLATE 13



FORE & AFT LEVEL & SIDE SLIP INDICATOR

CHAPTER XXXI

The Fore and Aft Level

The fore and aft level as shown in plate 14 consists simply of a triangular glass tube having a bulb in the apex of the triangle.

The tube is partially filled with a non-freezing colored liquid. The level is set flush with the instrument board and graduated in degrees, the zero degrees being in the half way position when the plane is flying level fore and aft. This level shows the pilot the degree of climbing or gliding angles of the plane under a given set of power or load conditions.

Unlike the air speed meter, which as we know shows the pilot at all times whether he is flying within a safe margin of speed, the fore and aft level cannot be used to check the climb as a plane might climb at a certain angle with a full "gun" and a light load while with a full load and a failing engine the angle of climb would be less.

The greatest value of the instrument lies in its use on bombing and photographic planes where it is imperative that the craft be kept on a level keel.

Care must be used when installing to have the bubble at zero degrees when the plane is exactly level fore and aft.

No repairs or adjustments can be made on this instrument.

CHAPTER XXXII

The Gyro Turn Indicator

The primary purpose of the gyro turn indicator is to make fog, cloud and night flying easier and safer. It does this by showing, instantly and accurately, the least divergence from straight line flight.

Its mechanism is extremely simple. A small gyro, on a lateral axis, is spun to about 5000 revolutions per minute by the suction obtained from a venturi tube placed in the air stream and connected to the instrument by a length of tubing. The frame holding the gyro bearings, is hung on a fore and aft axis, but its rotation about this axis is restrained by light centralizing springs.

The action of the instrument depends upon the well known law of gyroscopic precession—that is, any rotary motion transmitted to a gyro (except motion about its own axis) causes the gyro to move, not in the direction of the applied motion, but at right angles to it. This motion at right angles to the applied motion is called "precession." Furthermore, the speed at which a gyro will "precess" is many times greater than the speed at which the rotary motion is applied to it.

The operation of the indicator is thus very simple. When the airplane starts to turn (about a vertical axis) the rotary motion causes the gyro to precess (about a horizontal axis) and this precession, many times greater than the turning motion of the airplane, is indicated on the dial of the instrument. Were it not for the centralizing springs, the slightest turning motion of the airplane would cause the gyro to precess all the way round. The springs are used, therefore, to restrain the action and so that fast or slow turns produce

large or small indications. As soon as the turning motion ceases, the springs return the gyro to the neutral position.

Any one who has had the disconcerting experience of finding himself in fog or cloud, with no means of knowing when he was turning, will appreciate what a tremendous advance in the art of aerial navigation is made possible by this little instrument.

The Gyro Turn Indicator, complete with a venturi tube for operation, weighs but $1\frac{3}{4}$ pounds. The power required to operate the instrument is no more than that needed for an air speed indicator.

CHAPTER XXXIII

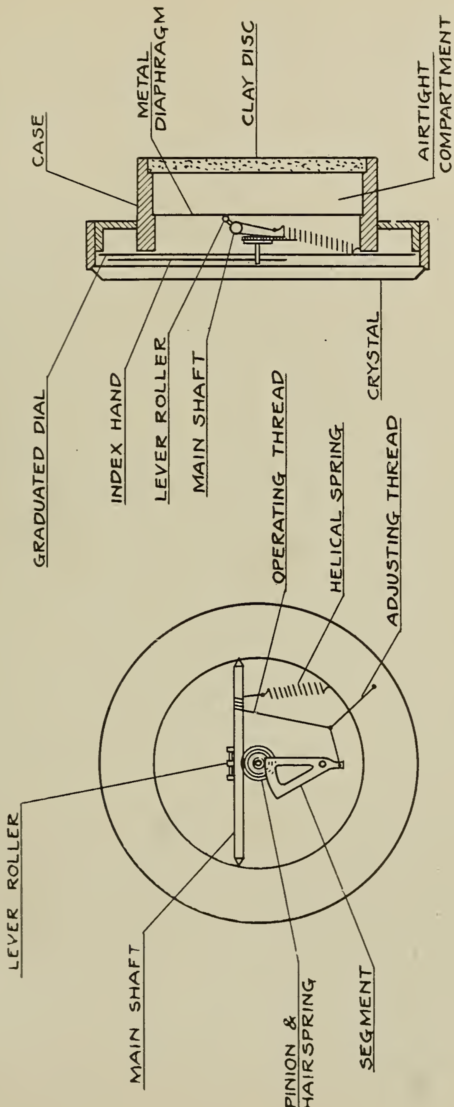
Hydrogen Leak Detector

The hydrogen leak detector shown on the following page is mounted for use in a circular wood frame about 10 inches in diameter. The dial can be read on the front of the frame, while the back of the frame is covered with a perforated metal plate and a disc of wire gauze to protect the clay disc of the instrument from injury.

To operate, the frame is laid against the gas bag with the perforated plate inward and the dial facing the operator. Hydrogen leaking from the gas bag anywhere in the area covered by the frame passes through the perforated plate and wire gauze and comes in contact with the clay disc. This disc is impervious to air, but permits the passage of hydrogen, which, when it passes through into the air tight compartment increases the pressure in this compartment and forces the flexible metal diaphragm out slightly. This movement is transmitted through the lever roller, lever, and shaft and slacks the operating thread against the pull of the helical spring. The hair spring takes up this slack through the pinion, and gear sector, causing the index hand to move on the dial.

After the test, and when the hydrogen in the air tight compartment has been allowed to escape through the clay disc, the diaphragm returns to its normal position, and the helical spring, which is more powerful than the hair spring, pulls the thread back to its original position and causes the index hand to return to the zero mark on the dial.

In order to compensate for temperature and barometric pressure variations, and in order that the index hand will



HYDROGEN LEAK DETECTOR

point to zero on the dial when there is no hydrogen in the air tight compartment, an adjusting thread and clamp is provided. See plate 14.

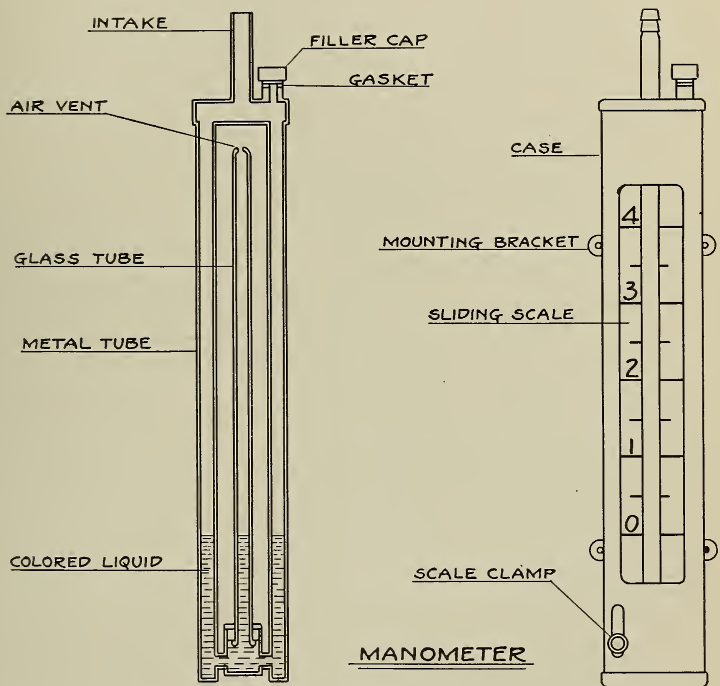
CHAPTER XXXIV

The Manometer

The U-tube manometer is an instrument used to register the gas pressure in balloons and ariships and air pressure in ballonets.

The instrument is composed of three tubes, two of which are metal, and one of glass, which gives the readings. The two metal tubes are placed one on each side of the center glass tube and are connected to each other at both ends by small reservoirs. The glass tube is only connected to the lower reservoir and has a very small air hole in the top end. The lower reservoir is filled with a kerosene mixture.

When the pressure is placed on the instrument, it travels down the two metal tubes to the lower reservoir where it forces the liquid into the glass tube. As the liquid travels up the glass tube, it forces the air out through the small hole at the top. As the pressure drops, the action is reversed. See plate 15.


INTAKE
FILLER CAP
GASKET
AIR VENT
GLASS TUBE
METAL TUBE
COLORED LIQUID
CASE
MOUNTING BRACKET
SLIDING SCALE
SCALE CLAMP
4
3
2
1
0
MANOMETER

CHAPTER XXXV

The Statoscope

Strictly speaking, statoscopes are used mainly on airships and free balloons but are sometimes used on airplanes in tests.

There are two types of statoscopes, namely: the liquid and diaphragm. The liquid type is the simpler of the two as there is no mechanism to get out of order. The various diaphragm types are similar in design and construction but are rapidly falling into disuse, owing to the rapid deterioration of the rubber diaphragm.

THE LIQUID TYPE

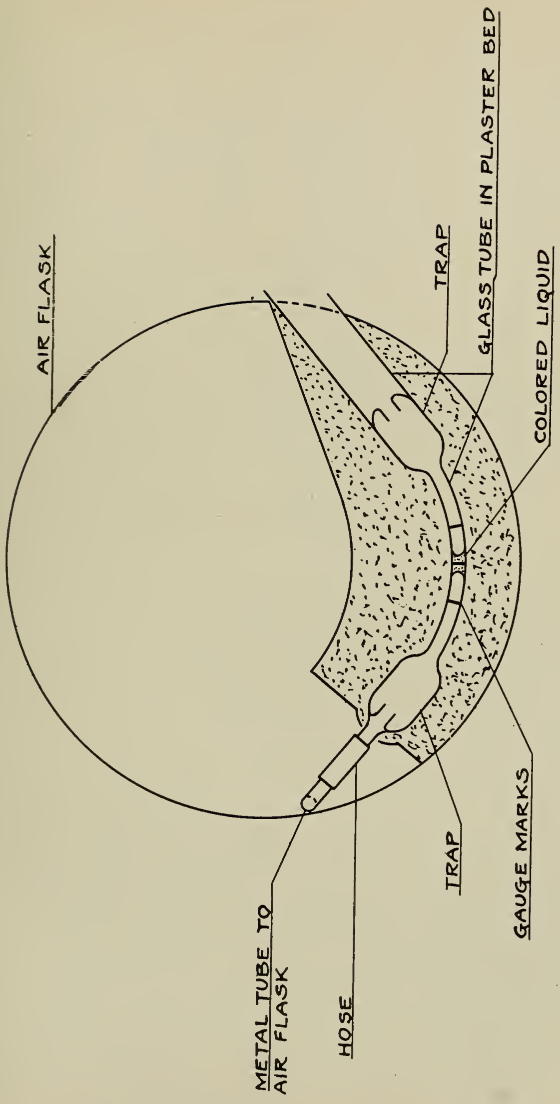
It consists of a curved glass tube which is enlarged at both ends, one end leading to an enclosed reservoir and the other end is open to the atmosphere. A small drop of oil (about $\frac{1}{4}$ inch long) is dropped into the tube, thus sealing the air in reservoir.

When ascending, atmospheric pressure grows less, so the pressure in the reservoir becomes greater than the pressure outside and as a result the liquid is forced towards the outlet end in order to equalize the pressure. The instrument is extremely sensitive and in order to prevent the bubble from getting to the end of the tube too quickly, the ends are enlarged. On reaching the enlarged end, the bubble will break run down toward the bottom part of the tube and form over again. If the instrument is still going up, the procedure will be repeated. A trap is placed in each end of the tube so that the instrument may be carried in any position without losing

the oil. The entire instrument is wrapped with an insulating composition, such as cotton, felt, or similar substance, to protect it from sudden temperature changes. This substance must not be removed when the instrument is in operation.

The black marks on the narrow portion of the tube are placed there in order to aid in the reading of slight changes. A well made instrument will register changes of elevation as small as one inch while changes of 10 feet or more will register on the crudest of instruments.

The liquid is a kerosene mixture to prevent freezing. See plate 16.


AIR FLASK
TRAP
GLASS TUBE IN PLASTER BED
COLORED LIQUID
METAL TUBE TO
AIR FLASK
HOSE
TRAP
GAUGE MARKS

STATOSCOPE

CHAPTER XXXVI

Balloons

The first balloon said to have been flown for public exhibition was on June 5, 1783, by Joseph and Steven Montgolfer. The first man to go up in a balloon was said to have been a man by the name of Rozier, who ascended in a captive balloon to a height of about 80 feet, in the latter part of the year 1783. Later, in company with a companion, he made a voyage in a free balloon, remaining in the air about half an hour. These balloons were inflated by hot air and by means of a fire pan carried immediately below the mouth of the bag the air was kept at sufficient temperature in order to keep them in the air.

The first really successful free balloon crossed the English Channel in 1785. An Englishman by the name of Blanchard and an American by the name of Jeffries started from Dover on January 7 in a balloon equipped with wings and oars. After a very hazardous voyage, during which they had to cast overboard everything movable to keep from drowning, they landed in triumph on the French Coast. An attempt to duplicate this feat was made shortly afterward by Rozier. He constructed a balloon filled with hydrogen, below which hung a receiver in which air could be heated. He hoped to replace by the hot air the losses due to leakage of hydrogen. Soon after the start the balloon exploded, due to the escaping gas reaching the fire, and Rozier and his companion were dashed on the cliffs and killed.

The fact that the invention of the airship and means of navigating it were almost simultaneous with the free balloon and the principles upon which success has been achieved were laid down within a year of the appearance of

Montgolfer's first gas bag. The development was very much retarded by the lack of suitable means of propulsion and the actual history of what has been accomplished in this field dates back only to the initial circular flight of La France in 1885. Lieutenant Meusnier, who subsequently became a General in the French Army must really be credited with being the true inventor of aerial navigation. At a time when nothing whatever was known of the science, Meusnier had the distinction of elaborating at one stroke all the laws governing the stability of an airship and calculating correctly the condition of equilibrium for an elongated balloon after having strikingly demonstrated the necessity for its elongation. This was in 1784 and Meusnier's designs and calculations are said to be still preserved in the engineering section of the French War Office in the form of drawings and tables.

But as often proved to be the case in other fields of research, his efforts went unheeded. How marvellous the establishment of these numerous principles by one man in a short time really is, can be appreciated only by noting the painfully slow process that has been necessary to again determine them, one by one, at considerable intervals and after numerous failures. Through not following the lines which he laid down, aerial navigation lost a century in futile groping about; in experiments absolutely without method or sequence.

It is to be noted that during the period between 1784 and 1885 the development of the airship was very much retarded by the lack of suitable means of propulsion. Therefore, all of the laws governing the stability of an airship and calculating correctly the equilibrium for an elongated balloon were not put into practice until the latter date mentioned.

Q. How many kinds of gases are there used for ballooning?

A. Three—hydrogen, helium and coal gas.

Q. Which has the greatest lift?

A. The lift of the foregoing gases is as follows:
Hydrogen, helium, coal gas.

Q. Which is the best gas of the three?

A. Helium is the best of all known gases for ballooning owing to it being non-poisonous and non-explosive, but its use is limited at the present time, owing to limited quantity available and its excessive cost. Hydrogen is the best of the three if cost and buoyancy are taken into consideration, but it is highly dangerous when impure, and is subject to ignition through both spontaneous combustion, static electricity, fire, etc. Coal gas is only used for free balloons and those carrying a large volume of same as its lift is only about one-half that of hydrogen, its cost being less than one-tenth of that of hydrogen.

Q. How many processes are there for making hydrogen gas, and which is the cheapest?

A. There are various methods for making hydrogen gas. Some of them are as follows:

1. *The Electrolytic Method*, which is the process of separating the hydrogen from the water by means of an electric current. By this method 1 kilowatt hour of electric power will produce about 7½ cubic feet of hydrogen at a cost of about $8.00 per 1000 cubic feet.

2. *The Silicon Process:* The chemical reaction producing hydrogen is between silicon and caustic soda without any change in the iron. Ferro-silicon is used by the French and British, being more easily secured and at less cost than the pure silicon. Ferro-silicon contains from 50 to 75 per cent silicon. It is believed that to produce 1000 cubic feet of hydrogen by this method 39.6 pounds of pure silicon and

112.3 pounds of pure caustic soda will be required. The actual quantity produced depends upon the purity of silicon and caustic soda. The ferro-silicon has been found to produce as high as 85 per cent silicon.

3. *Steam and Iron Process:* Hydrogen is made by passing steam over the red hot iron ore. The steam is decomposed into its constituent elements, the iron ore absorbing oxygen from the steam and the hydrogen being collected. It is believed that 3500 cubic feet of gas per hour can be manufactured by this process, at a cost of from $5.00 to $7.00 per 1000 cubic feet. This process is the one now used at Pensacola, and it is believed that the cost can be considerably reduced by running the plant continuously, which is not done at present.

4. Another process is the vitriol process, which is the action of sulphuric acid on iron or zinc, evolving hydrogen. It seems that 150 pounds of iron and 275 pounds of sulphuric acid are required to produce 1000 cubic feet of hydrogen, and 182.5 pounds of zinc and 275 pounds of sulphuric acid are required for 1000 cubic feet of hydrogen.

5. *The Hydrolythe Process:* To produce hydrogen by this method it is only necessary to drop the granulated hydrolythe into the water. Not extensively used due to high cost of hydrolythe. To produce 1000 cubic feet of hydrogen only 59 pounds of hydrolythe are required. There are several other methods, but the steam and iron process seems to be the cheapest and used most extensively at present.

The above mentioned gases are the principal gases used for ballooning. Natural gas can be used as well as those previously described. It consists of about 90 percent marsh gas and 10 per cent of other hydro-carbons. It is a very explosive gas, being similar in composition to the fire damp found in coal mines. It is a cheap gas, but has very little lifting power. Its lift is about equal to that of air heated

from 60°F. to 150°F. Its specific gravity averages about 0.66.

Water gas is so called because it is made from water or steam. It constitutes the basis of the illuminating gas used in most cities at the present time. Super-heated steam is passed through red hot carbon, either in the form of coke or hard coal, giving the following reaction: $H_2O + C = CO + 2H$. This combination of CO and H being water gas.

Hot air gas has been used to a certain extent for exhibition free ballooning, but it is not suitable for airships or free balloons, and it is not considered safe to descend with a hot air balloon, hence the descent is always made by a parachute where hot air is used.

The question as to the cost of producing hydrogen varies considerably in that the cost of materials varies more or less and the length of time the plant is operated, particularly the iron contact process, which plant, in order to obtain the best results, should be operated day and night, and while hydrogen can be manufactured cheaply by this method it will be found, when the cost of renewal of equipment is taken into consideration, such as the periodical renewal of retorts, that the cost of producing hydrogen by this method is liable to be misleading. It is to be noted that by the electrolytic method hydrogen can be manufactured for from $8.00 to $10.00 per 1000 cubic feet. Under the silicon process, according to the chemical action to produce 1000 cubic feet of hydrogen would require 39.6 pounds of pure silicon and 112.3 pounds of pure caustic soda. The actual quantities which should be supplied depend upon the silicon content of the ferro-silicon and the percentage of purity of the caustic soda. It has been ascertained that 58 pounds of 80 percent ferro-silicon and 125½ pounds of caustic soda would produce 1000 cubic feet of hydrogen. Ferro-silicon at 15 cents per pound and caustic soda at 3 cents per pound would bring the total cost for material to $12.46 per 1000 cubic feet. In connec-

tion with the manufacture of hydrogen by the silicon process, it is to be noted that ferro-silicon may be stored without deterioration by moisture and without any special precautions for its care. However, such is not the case with caustic soda, which must be protected from moisture.

Q. What should be the percentage of purity of this gas as manufactured?

A. The percentage of purity of hydrogen gas as manufactured at Pensacola averages 99.8 per cent pure (steam and iron process), the electrolytic process 99.9 and the silicon process 99.8.

Q. What is diffusion?

A. By diffusion (with reference to ballooning) is meant the volume of gas which passes through a unit area of balloon fabric in a given time under certain or standard condition. These requirements vary greatly with the purpose for which the fabric is to be used, as for instance a free balloon need not be so tight as an airship.

PERMEABILITY TEST

The permeability of the fabric to hydrogen shall be determined from a representative specimen of the fabric selected from the test sample under the following conditions and by an approved method and apparatus. The fabric shall be maintained during the period of test at a temperature of 25° C., and a current of pure, dry hydrogen shall be maintained on one side of the fabric during the period of test under a pressure of 30 mm. of water above the pressure on the reverse side of the the fabric. Dry air at approximately atmospheric pressure shall be passed over the reverse side of the fabric, and the hydrogen passing through

the fabric shall be determined either by burning to water and weighing as such or by any other accurate method, such as using the gas interferometer. If the combustion method is used, the fabric should remain in the apparatus in contact with the atmosphere of pure hydrogen for a sufficient period to reach equilibrum before beginning a test. The permeability shall be calculated in liters of dry hydrogen, measured at zero degrees centigrade and 760 mm. mercury pressure, and shall be expressed as the permeability in liters per square meter per 24 hours which shall not exceed the maximum called for.

Q. How is the purity of the gas tested in a balloon or airship and how often?

A. The hydrogen gas contained in an airship is tested by two methods: First, the pyrogallic acid absorption outfit; Second, the Edwards effusion meter.

In testing with the absorption outfit, the manometer tube is taken from the manometer and placed on the inlet tube of the absorption outfit. One hundred cubic centimeters of hydrogen are taken into a pippette graduated in tenths of cubic centimeters in the absorption outfit. After this gas has been taken in, it is forced through a pippette containing broken glass tubing saturated with pyrogallic acid. The pyrogallic acid robs the balloon gas of the oxygen contents. After washing two or three times the gas is brought back, and measured in the tube graduated in tenths of cubic centimeters and subtracted from the original amount, which was one hundred cubic centimeters. The difference in the two volumes is the oxygen content of the gas, which has been absorbed by the pyrogallic acid. As oxygen is approximately one-fifth of the air content, this result is multiplied by 5 which gives the total impurity of the balloon gas; total impurity being air.

EDWARDS EFFUSION METER

The construction of the meter includes a glass jar in a water jacket with two hair lines on it. It also includes an orifice and a levelling bottle which is filled with water. In testing hydrogen gas with this type of meter, the manometer tube is disconnected from the manometer and connected to the meter same as for other outfit, and gas from the airship is allowed to pass into the meter through a stop cock, which is shut off immediately after the entrance of the amount required for the test. The gas is then forced through the orifice by means of the levelling bottle filled with water. From the time that the water level forcing the gas through the orifice reaches the first hair line in the jar until the time that the water level reaches the second hair line, this passage is timed with a stop watch in fifths of a second. This operation is carried out three times and the average taken. Then air is taken and a similar procedure followed, repeating three times. The gas time is divided by the air time and a factor or number thereby obtained. From this factor the specific gravity of the balloon gas is determined by referring to a chart or conversion table, and from the specific gravity the purity of the balloon gas is determined.

Q. What is meant by purging a balloon?

A. Purging is the substitution of pure gas for a quantity of impure gas contained in an airship. To purge a balloon either one or both of the ballonets may be used. The amount of gas necessary to bring the purity up to a safer margin may be from 20,000 to 30,000 cubic feet. The ballonets in an airship being about 25 to 30 per cent capacity of that of the gas bag can be filled with air, valving the gas from the bag proper as ballonets become full. The gas valve is then closed and new and purer gas is started into the gas bag.

The valves of the ballonets being opened the air is forced out until the diaphragms of the ballonets lie flat on the bottom of the balloon and the gas pressure shown by the manometer is $\frac{1}{2}$ inch or 1 inch as may be desired.

Q. If, on testing, a balloon shows 18 per cent volume of air, what percentage of oxygen would it contain?
A. About 3.6 per cent of oxygen.

Q. What percentage of air is oxygen by volume?
A. Approximately one-fifth.

Q. What is a comalong and for what purpose is it used?
A. A comalong is a cable grip, used for hauling taut suspension wires on airships or it can be used on wire where slack in same is desired to be taken up. As a rule comalongs or cable grips only have a range for about three different diameter wires. Therefore, a comalong for use on $\frac{1}{4}$ inch or $\frac{5}{16}$ inch diameter cable would not be suitable for $\frac{1}{2}$ inch diameter cable, this being governed by the size of the jaws and the depth of groove in same. The comalong is operated by pulling the lower jaw towards you and pushing the upper jaw away from you, thus opening the jaws. Place wire between the opening between the upper and lower jaws and let go the jaws. It will automatically grip the wire on account of a spring arrangement which causes jaws to close. A small jigger or tackle is then attached to the eye and cable is hauled taut.

See figure on following page.

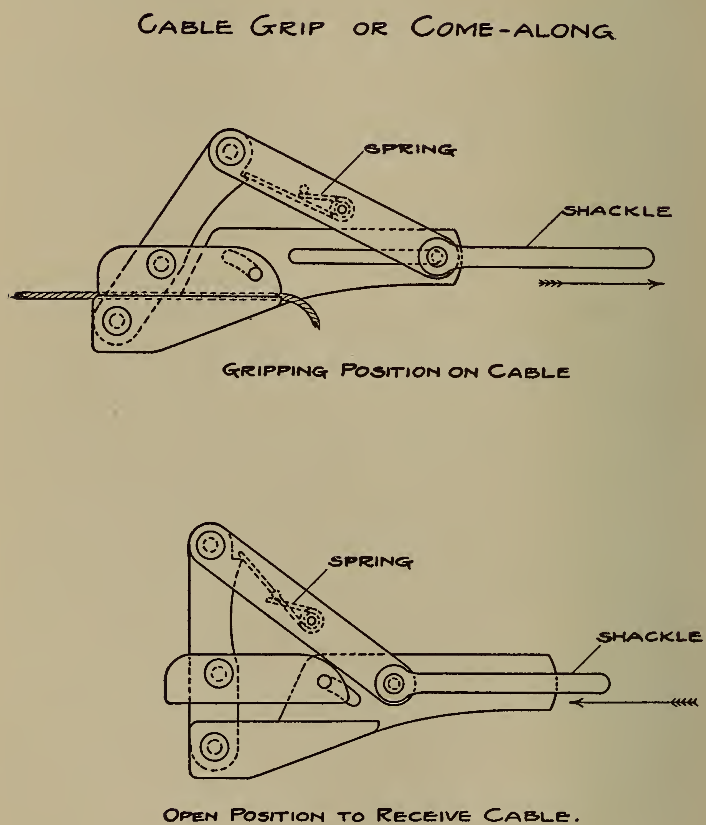

CABLE GRIP OR COME-ALONG
SPRING
SHACKLE
GRIPPING POSITION ON CABLE
SPRING
SHACKLE
OPEN POSITION TO RECEIVE CABLE.

Fig. 22

CHAPTER XXXVII

Transportation of Gas

Q. How many means are there for transporting gas?

A. Three—by the means of nurse balloons, steel bottles and gas pipe lines.

Nurse. Gas is often transported from one place to another by the use of the "nurse" when the distance is not too great. The "nurse" is nothing more than a fabric container holding probably 5000 cubic feet of gas. This bag is usually made cylindrical with hemispherical ends and equipped with ropes on either side for the purpose of transporting it from one place to another.

Bags of sand are attached to these ropes so that the weight of the sand almost equals the lift of the gas. In this way, the only force to overcome is that due to the wind.

In crossing wires, the first pair of ropes are thrown over the wires and caught again on the other side, then the second pair, etc., until the gas bag has been literally carried over the wires. The gas can be taken from the "nurse" in two ways, either by the application of pressure on the bag, or by having the outlet in the top of the bag and depending upon the lightness of the gas to leave the bag, or both.

Bottle. The most usual method of transporting gas is by the use of gas bottles. These bottles vary in size, the most usual size having a total height of about 4 feet 3 inches and an outside diameter of approximately $8\frac{1}{2}$ inches. These bottles are pressed from steel and have no seams. The wall of these bottles is from $\frac{1}{4}$ to $\frac{1}{2}$ of an inch thick. When charged to a pressure of 1800 pounds, which is the usual pressure to

which these bottles are filled, they contain a quantity of gas which when released to atmospheric pressure has a volume of from 175 to 200 cubic feet.

A specially constructed needle valve is required to prevent the escape of gas at this high pressure.

When emptying these bottles a great decrease in the temperature takes place at the valve due to the sudden adiabatic expansion of the gas, causing frost, and even freezing the outlet completely shut, cutting off the supply of gas and giving the impression of an empty bottle. The valve must be thawed out before the remainder of the gas can be obtained. This freezing can be eliminated and the entire quantity of gas discharged quicker by opening the valve only part way, hence keeping the gas temperature from dropping to such a low degree. After the pressure in the bottle has decreased somewhat, the valve may be opened wider.

For military purposes, trucks are arranged with shelves so that several layers of bottles can be transported at the same time; the bottles are all clamped in place so that they cannot jar about. In order to facilitate rapid gas bag inflation, all of the bottles of each row are connected to one main and the several mains connected together, so that all that is necessary to discharge the contents of perhaps two dozen bottles is to attach the inflation tube to this manifold and turn all the valves slightly.

For storage and transportation afloat bottles would be used.

CHAPTER XXXVIII

Interior Inspection of Balloons and Airship

Q. What inspection is necessary before inflating a free balloon, kite balloon and airship with hydrogen?

A. Before inflating a free, kite balloon, or airship with gas: The bag should first be spread out on the ground cloth and inflated with air to about one-quarter full, for the purpose of inspecting the fabric, seams and rip panels, and all valve openings, also glands and appendix connections inside and out. Depending on the size of the bag, the inspection crew may consist of four, six or ten men and in larger types of airships larger crews. The fabric is inspected for scratches and pin holes; deep scratches often occur where the bag comes in contact with the floor. Places may be worn where ropes rub on the bag during inflation. Seams and the tape covering them are examined to see that all are sound and in perfect condition. An examination of the fabric and stitching and cementing of all finger patches, fins and rudder connections, ballonet diaphragm, and in the case of kite balloon the belly band and lobe connections. In this connection it is noted that one crew works on the outside of the bag while another is inside, the work being done systematically, each block of fabric being gone over carefully. In order that the minutest hole can be detected a man on the outside of the bag has a rectangular shaped box with three or four electric lights therein, which he holds up against the fabric and passes over a section at a time, in order that the man on the interior of the bag can readily detect same. By this means any hole, no matter how small, is easily detected from within, this however is only used on airship inspection.

Note: Before entering any balloon or airship for inspection purposes or otherwise, make sure that the bag has been fully deflated and that no hydrogen remains before partially inflating the bag.

Q. If, upon inspection, any holes or thin places are located, state in detail how same may be remedied.

A. If any holes are found, cut a patch to cover and wash both surfaces with benzine. Apply three coats of pure rubber cement both to the balloon and the patch, allowing sufficient time for the first and second coats to dry and enough time for the third to become tacky, then apply the patch and roll hard, care being taken to get all air pockets out and the edges tight, then apply soapstone to prevent sticking. For small holes a fabric patch on the inside only is necessary, larger ones inside and out, scalloping the edges of the patch, and making the inner patch slightly larger. Holes requiring a patch with a side more than twelve inches are usually done by an experienced man, and the rule is that the edge of the patch should in no case be nearer than three inches from the edge of the hole. When large areas of thin fabric are found, they are usually repaired by removal of the panel, or block as sometimes called, and this work must be done by experienced and efficient men after the bag has been deflated, the tape inside and out being removed and the panel carefully cut out, a new panel cut to fit the edges, having a lap of about one inch. The edges of the new panel for $1\frac{1}{4}$ inches are cleaned with high test benzine, also the edges of the opening in the bag, and three coats of pure rubber cement applied with fifteen minutes between each coat. As soon as the last coat becomes tacky the patch is applied and care taken to get all wrinkles and air pockets out by running a small steel roller well over the seams. The seams are then double stitched and then prepared with two coats of cement

and tape applied and rolled down well, especially on the edges of the panel fitted. The patch is then coated with the airship dope (Delta Dope) inside and out.

Q. In valving a balloon to relieve gas pressure does or does not a certain amount of air enter the balloon at the same time? If so, what percentage of volume in proportion to the amount let out?

A. It is believed that a certain small amount of air does enter a balloon when it is being valved to relieve gas pressure, about 0.4 per cent of volume in proportion to the gas let out.

Q. What is a rip panel and for what purpose is it used?

A. A rip panel is a part or section of a balloon so constructed that it can be opened at a monent's notice to allow the gas to escape more rapidly than the valves would allow and is so located as to be at the top of the bag in a spherical balloon or any other type. The opening, when panel is ripped, if old type, is about 4 inches wide and varies in length from 6 to 18 feet, depending on the size of the bag. And if the new type, the rip panel consists of a series of openings about 8 inches by 12 inches, elliptical in shape, and about 8 to 12 inches apart, and in a straight line so that a narrow strip of fabric will cover all of these openings, used in kite balloons only. A panel of this type is considered stronger, and there is less danger of the balloon being ripped by the wind beyond the point intended, as might be the case with the first type mentioned. The panel proper is a strip of fabric wide enough to allow for cementing and sewing it to the balloon at edges only and for a length sufficient to allow for turning the upper end back over a toggle to which the rip cord is attached. The cementing at this end of the panel is brought to a sharp point after clearing the margin of the last opening. This is to make the rip start easily and without

tearing the fabric. The principal use of the rip panel is to deflate the balloon rapidly in the case of an emergency when it is not safe to undertake to make a landing by valving.

Q. State in detail how you would put a rip panel on a free balloon, airship or kite balloon.

A. In a free balloon the rip panel is located in the upper hemisphere, the top of the panel being about 4 feet from the valve hole, and running in the direction of a meridian. The length of the panel, if of the slot type, is usually one-sixth the circumference of the bag, or from 12 to 24 feet in length and 4 inches wide, depending upon the size of the bag. This type of rip panel is installed in the following manner: The section where panel is to be cut is reinforced with two thicknesses of balloon fabric cemented to balloon, one inside and one outside, the inner being about 10 to 12 inches wide and the outer 9 to 11 inches, and about one foot to 14 inches longer than the slot is to be. The slot is then cut through the bag and reinforced and the edges of the slot taped with a 2-inch tape which leaves nearly one inch inside and one outside, a double row of stitchings then runs around the slot through fabric and tape. This will prevent the tape from becoming loose and keep the edges of the slot in good condition for replacing the rip panel from time to time. The panel itself which is cemented on to the balloon over the slot on the inside is made of two to four thicknesses of balloon fabric cemented together. The edge is taped, the ripping end of the panel is folded back over a toggle, and this fold back is cemented down to the panel itself. The panel is cemented to the balloon. Beyond the ripping end of the panel there is cemented to the balloon an anchor patch. The ripping end of the panel is tied to this patch by two breakable cords which are of different lengths so that one breaks before the other. There is also another

small patch with breakable cords to take the weight of the rip cord. A pull of 30 pounds is required to break these cords before the panel will start to rip. This is an extra precaution. Additional patches with breakable cords may be placed to suit the lead of the rip cord down to the car, in some cases tape being used on the outside. One other type of rip panel used at present is that of a series of elliptical holes, 8, 12 and 16 holes being cut through the reinforced fabric, the edges taped, and in some cases rope grommets are used on these edges for reinforcements. The holes are spaced 4 to 6 inches apart and the rip panel is cemented on to the balloon from the inside, edges and ends only, no cementing to the space between each opening. The panel itself is of two thicknesses of fabric with the edges taped, and the ripping end same as that mentioned above. There seems to be a great advantage in the strength of this type of rip panel over the slot type, but it is believed that the slot type is the most efficient type when it becomes necessary to make use of the rip panel of a balloon. In a number of ships built for the Navy three and even four rip panels have been fitted, two on the bow and two near the tail or on the quarter on either side of the ship. This is an advantage for when ripping the panel in the bow of a ship which is headed into a strong wind the wind will tend to keep the gas in the bag, and by ripping one or both of the rear panels the gas will be driven out by the wind much more rapidly. This also would apply when ship was broadside to the wind. The panels on the opposite side could be ripped in order to deflate and save the ship. Also another type has rip panels from which the rip cords lead so that they can be ripped singly or collectively. This permits the rip cords to be tied to a mooring post when the ship is anchored. The R and M type kite balloons are fitted with one rip panel forward near the nose at the greatest diameter of the bag; in the

R type the rip panel is transverse and of the elliptical hole type. In the C type ship two panels are fitted in the top. Rip cords are always colored red.

Q. What is delta dope and for what purpose is it used?

A. Delta dope conforms to airship dope specifications No. 44 and the solvent and thinner to specification No. 45. It is used to dope the inside and outside of airships and balloons, and its principal function is to make the bag gas tight. When carefully and evenly put on, it has a smooth finish film and offers a greater resistance to gas leakage than plain dope, and on account of the castor oil in it reduces somewhat the tendency to crack the surface.

Q. For what purpose is powdered aluminum used on a balloon?

A. Powdered aluminum is used on balloons for radiation purposes. The outside surface of the body painted with dope or varnish containing aluminum of 5 to 8 per cent (by weight) to the gallon reflects the heat from the sun more effectively than any other material used in painting balloons or airplane wings, thus keeping the temperature inside the balloon as low as possible.

Q. What percentage of powdered aluminum by weight should be put in each gallon of dope?

A. From 5 to 8 per cent by weight powdered aluminum should be put in each gallon of dope for the outside of a balloon.

Q. How many square feet of surface will delta dope cover per gallon?

A. In the first coat work 125 square feet per gallon; in each additional coat 150 square feet per gallon, dope containing aluminum about 125 square feet per gallon.

Q. What methods are used in applying this dope and describe same?

A. There are two methods, the spray guns and brushes. The former method always gives the best results. The bag is inflated with air and kept well ventilated for the inside doping, the crews being changed quite often in order that no one may be overcome by the fumes. The bag is rolled from side to side on the ground cloth as the dope is applied, the gangs taking the width of one or two gores at a stretch until the entire bag has been coated. The gore is the panel running lengthwise with an airship or kite balloon, and the perpendicular panels in a free balloon are the gores. The rings are the transverse or horizontal panels. The usual precautions of seeing that the bag has been fully deflated and that no hydrogen remains when the bag is inflated with air in order to work in same should be observed.

Q. What is a gammeter valve and for what purpose is it used?

A. Gammeter is the name of the person who designed the balloon valve of that name. It is used in kite balloons and airships both for air and gas valves, works by hand and automatically when adjusted for certain pressure. Is used to relieve gas or air pressure in the envelope and ballonets. The gammeter valve is an all metal valve, while free balloons are fitted with a wooden valve operated by hand only.

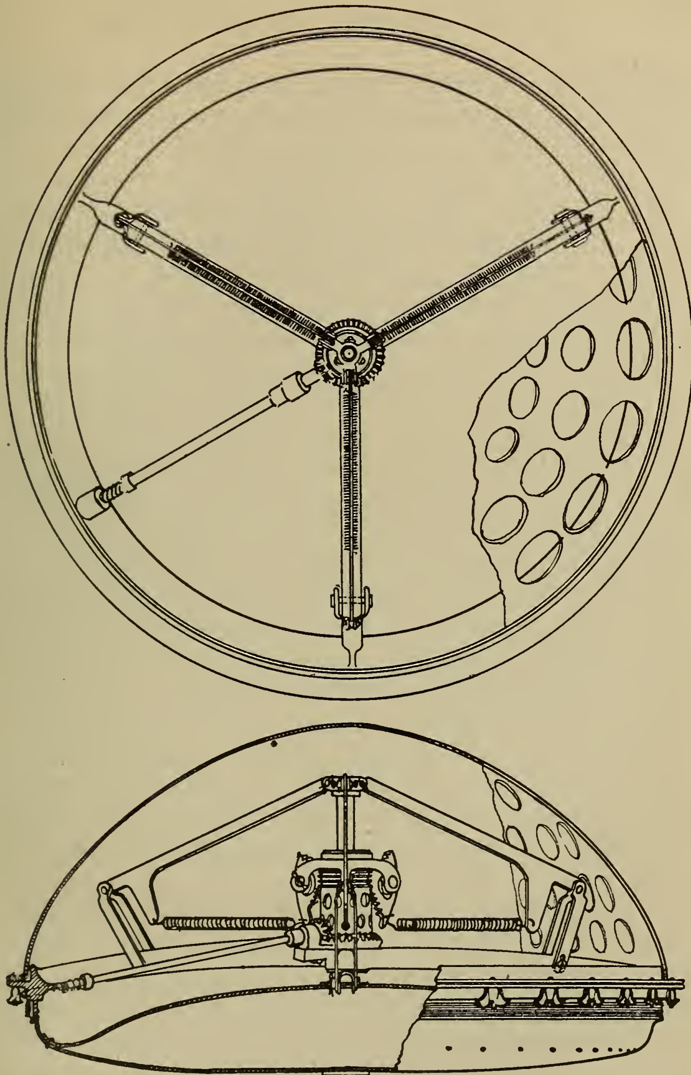
Q. Describe a gammeter valve.

A. The gammeter valve is composed of the following parts: An aluminum ring with three bars connecting to a center post, or barrel; in this barrel is fitted a sliding bolt or pin, to which three arms connected by pin connection at top

of sliding bolt and at lower end by a short rocker arm to the fixed arm of the frame. Also three spiral springs, one for each arm, connect to the lug on each arm and to an adjustable nut at the upper end of the barrel. There is also an adjusting mechanism for setting the valve to open automatically at a certain pressure from within. There is another clamping ring with wing nuts for clamping the envelope fabric between ring and valve frame. A cover of aluminum which is attached to the lower end of the sliding bolt, is slightly belled at edges and fitted with a flange which forms a suitable seat for the rubber gasket which is held in place by metal clips or by a wrapping of harness twine. The outside surface of the cover is practically flat except as noted above and has an eye in the center to which the valve cord is attached. On the inside of the valve cover there is a thin sheet of aluminum riveted at edges which rises cone shape to the bottom of the fixed arms of the valve frame. A guard made of aluminum sheet lightened with several 2 inch holes, cone shaped, is fitted on the inside of the valve ring. This guard protects the post adjusting and operating gear of the valve from all except dust, sand or other small particles that may be in the air. The moulded rubber gasket fitted as above mentioned to the cover seats on the smooth flat surface of the main ring of the valve frame, and if kept clean and in good condition makes a very gas-tight joint. The gammeter valves used in kite balloons and airships are 12 and 18 inches in diameter. The valve can be adjusted before or after installation in the envelope as the adjusting screw is located on the outer surface of the valve. There is also fitted on the outside of the valve a yoke with a tripping lever and spring. (See Fig. 23.)

Q. What is the valve seat composed of?

A. The valve seat is composed of a moulded rubber



GAMMETER . VALVE

Fig. 23

gasket with the flange about $\frac{5}{8}$ inch wide, and secured to the cover by metal clips or by a wrapping of harness twine, also cemented to the flange of the cover.

Q. How is a balloon of any kind inflated from flasks?

A. In inflating a balloon from flasks, compressed gas is used. Cylinders containing about 180 cubic feet each of hydrogen gas are placed at the end of the hangar, that is if the balloon is in a hangar. The flasks are placed in stacks with the valve ends toward each other, with a passage between them just wide enough to allow for attaching the manifold connections to the cylinders. The cylinders are usually placed in groups of 100, 200 or 300, depending upon the capacity of the balloon to be filled. The cylinders are so arranged that connections to manifolds can be easily made without having to move anyone of the flasks. This is done by slightly staggering the successive rows of flasks toward the rear giving sufficient clearance for removing the screwed cap, making the connections and operating the valves. The manifold is usually of 6 branches, but may be of more, made of cast brass or bronze. The inside diameter is about $\frac{4}{5}$ inch, and the dead end of the manifold should be solid, not a mechanical or welded joint. The fabric inflation tube is connected to the manifold. This tube is 6 inches in diameter and the ends are usually made slightly tapered mouth shape, so that they will fit snugly over the sleeves used in connecting two lengths of tube together and the manifold fitting where it is held securely in place by a thorough wrapping at two points with marlin, friction tape or elastic bands. The manifold having been connected to the cylinders and the inflation tube to the manifold and the bag to be inflated, the operation should continue as follows: See that the bag or balloon is properly spread out and folds made so as to avoid friction and the inflation tube which

extends under the balloon properly cared for by placing sand bags about every 15 inches apart, staggering them on either side of the tube to prevent checking. Open the valves in the manifold branches. Purge inflation tube. Open main manifold valve. Open valves on the gas cylinders (flasks). Open valves gradually. When cylinders are considered to be empty, wait two minutes, then shut main manifold valve. Second shut valves on manifold branches, third shut valves on flasks. Disconnect and connect up to the next series immediately below, and continue as before. Watch manometer valve for pressure of gas in balloon, and when the desired pressure has been reached close valves as before mentioned, but do not disconnect until a suitable time has elapsed in which to note whether any serious leaks from valves or otherwise have occurred. When satisfied that all is well and pressure remains steady then disconnect. First tie the inflation tube (appendix) with marlin, elastic or friction tape, then all valves at manifold having previously been closed disconnect. The inflation tube is then rolled up slowly from one end, the other being open to allow the gas to escape. *Caution:* Never open the valves on flasks unless connected to the manifold for inflating, for if the flask is empty air will enter the flask. A very slight opening of the valve to a cylinder will prove whether it contains gas or not, and the valve should be immediately closed tightly. Other precautions: when about to start gassing a balloon in a hangar doors should be opened. No smoking within 150 feet of the operation, and no fire or open flame should be allowed in vicinity of the operation. Persons should not be allowed to loiter around near gas connections. Open sand bags should be distributed about and along the entire length of the inflating tube so that sand may be used to prevent fire spreading to or from the balloon by immediately dumping the sand on the tube or have inflation tube run under sand hopper that

can be dumped quickly. See that all manifold connections and flask connections are free of sand or other particles that may cause a spark by friction. Also, a spark may, in very warm dry weather, fly or jump from a person to any of the above parts mentioned that may become charged through friction. This also applies when valving a balloon in hangar. Persons should not be allowed to be closer than is absoutely necessary to operate the valve. Have fire extinguishers handy. Another precaution should be to wet the ends of the hose or inflation tube when it comes in contact with a metal sleeve, and in very dry weather it would be well to drive a metal bar or pipe into the ground and connect the cylinders to it, thus making a ground.

Q. If a balloon is in a hangar and she is being valved through one of the valves how far must a person remain away from this valve in order not to cause a static connection?

A. In order not to cause a static connection when valving from one of the valves of a balloon while in a hangar, it is best that the person or persons remain at least 6 feet away from the valve.

Q. If it is necessary for him to be inclose proximity to the valve what must he do in order to prevent a spark jumping from his body to the valve?

A. If necessary for a person to be in close proximity or to touch the valve, *or any other metal parts* of a balloon that is inflated, *they should first touch the fabric* of the balloon, thus grounding themselves. This, it is believed, will prevent sparks jumping from the body to the valve or other metal parts which may be highly charged.

Q. What is a finger patch and for what purpose is it used?

A. Finger patches are made of rope and rubberized fabric. An eye is formed in the middle of a piece of rope, in which a thimble or a ring may be inserted; the ends of the rope are frayed out to suit the number of fingers to the patch; if four fingers, two pieces of rope are used, if six fingers three pieces of rope. The ends are frayed and cemented between two thicknesses of fabric and well sewed. Another and stronger piece of rubberized fabric is fitted over the eye and cemented to the first. This is the outer surface of the finger patch. The ends of the rope having been frayed and divided into equal parts, cemented and sewed, the patch is then trimmed and resembles in a way a human hand of 4 to 6 fingers. The finger patch is used principally to distribute the load to as large an area of the balloon fabric as is possible. Used for suspension cables and handling ropes, also car and anchorage suspension, in fact, for most all connections to the bag of an airship. In a kite balloon the rigging (belly band) takes place of finger patches.

Q. How is a car connected to an airship and by what means?

A. A car is connected to an airship by means of fore and aft suspension cables, also thwart-ship or transverse suspension cables, These cables connect by means of wire splicing into the eyes of the finger patches, or by shackles and turnbuckles to finger patch and to car. The car suspension (C type airship) consists of some fifty finger patches, each of which is tested to withstand a pull of 2000 pounds. This type of rigging secures a very high safety factor and a considerable saving of weight over the belly band system. The location of the car is learned approximately from the blueprints, and when the car is lined up and weighed off the cables that are to be permanently spliced in connection to the car or at an equalizing ring or junction are spliced. In

the preliminary set up these wires are clamped in place. After the splices are made they are wrapped with wire and soldered, and in places where this type of connection is likely to rub or chafe the balloon fabric chafing patches are provided.

Q. How much tension should be placed in the various wires which connect a car to an airship?

A. The tension of all suspension cables should be in accordance with the tension diagram. A Larsen Tension Meter or some other reliable instrument should be used in order that undue strain is not put on individual cables, causing an excess strain on the finger patch to the extent of wrinkling the balloon fabric in the vicinity and especially about the patch. Tail droop is usually caused by too much tension on the rear ropes and makes the ship very hard to manage.

Q. How long should the balloon fabric last, assuming that same has received reasonable care?

A. It appears that the life of balloon fabric when well taken care of is from eighteen months to two years for balloons that have been in active service. It is believed that with good care and careful handling the life of a balloon fabric may be from two to three years. The method of storage of balloons now in use is at present not satisfactory, due to deterioration, in from six to eight months, considerable work has to be done before the balloon can be put in service. But until a better method is adopted the following should be observed. The bag being properly folded and covered with canvas cover for same (should be dry and cool when folding for storage) should be placed in a dark room of moderate temperature, dry, and suitable for warming in winter months; the wood parts should be kept dry but not too hot. Sunlight has a destructive influence on rubberized fabric, and balloons should not be left in the sun longer than is

absolutely necessary. Suspension cables and metal parts should be protected to prevent rusting.

Q. Of what kind of material is the rigging rope made of that is used in the free balloon, kite balloon and airship?

A. The material used in rigging ropes of a free balloon is made up of manila, also Italian hemp. The manila is hard laid and used mostly in American made balloons, while the Italian hemp is loose laid and soft in texture. The manila rope resists mositure to a certain extent, while the Italian hemp absorbs moisture freely, thus adding to the weight carried by the balloon, especially in damp, foggy and rainy weather and tends to fray out. The kite balloon also carries some rigging made up from steel wire, in the form of bridles for the purpose of anchoring the balloon, also for handling from a winch either on land or on board ship. Airships are almost completely rigged with steel wire cables in the form of suspension, anchorage and control cables. Also sections of handling lines are made up of wire cables to which manila or Italian hemp may be attached by reeving through the eye in the lower ends of these parts. A log line, or more properly speaking signal halyard, is used in all types of balloons for valve cords and rip panel cords. A manila hemp drag rope is also used in balloons.

Q. What is placed in the nose of a non-rigid airship to prevent same from collapsing from excess pressure in the nose when being driven through the air?

A. Box type battens are used on all non-rigid type airships in the nose. These battens are built up of spruce and veneer and are hollow in the interior, the length of the longest batten being approximately 12 feet, width $2\frac{1}{2}$ inches, thickness $1\frac{1}{4}$ inches, with filler blocks of $\frac{1}{4}$ inch spruce, spaced about $12\frac{5}{8}$ inches apart, the sides being enclosed with $\frac{1}{4}$ inch

spruce. These battens are held in position by patches which are cemented to the envelope battens being laced to patches.

Q. What kind of fabric is a balloon made of? How many plies?

A. Balloon fabric of 2 and 3 plies rubberized, and manufactured according to Navy Department's specification 113 and 14-B is used in making balloons for the Navy. Two-ply fabric with the warp of one ply running at an angle of 45 degrees to the warp of the other ply, with a gas film between, is used for the manufacture of kite balloons of the "R" and "M" types. The outside of the fabric is covered with a rubber compound which acts as a weather proofing. The finished fabric weighs about 9.5 ounces per square yard. Two- and three-ply fabric rubberized and with an inside proofing (rubber) in accordance with the specification mentioned above and an outside proofing and aluminum, and with the inside and outside plies straight, the center or middle ply on the bias and a gas film between each ply is used for airships, the three-ply fabric being used especially in multiple engine types. Note the ballonet fabric is also a little lighter than the main bag fabric, both plies straight. No compound on either side. There is, however, a gas film between the plies.

Q. What is a manometer gauge and what does it designate?

A. The manometer gauge consists of a glass tube mounted between two brass tubes. The brass tubes are connected at the top and bottom and with the manometer tube at the top so that the gas acts on both tubes. The glass tube connects with the brass tubes at the bottom and has a vent at the top for opening it to atmospheric pressure. The column of liquid in the glass tube, therefore, has the gas pressure in the balloon acting on one side of it through

the brass tubes and atmospheric pressure acting on the other side through the glass tube. The reading on the scale is therefore the difference in pressure between the pressure in the balloon and atmospheric pressure. The scale is placed over the brass tubes and bent back behind the glass tube and is graduated to read the pressure directly in inches of water when manometer liquid or colored kerosene is used in the manometer. Shows gas pressure in the balloon or air pressure in the ballonets.

Q. If a balloon having ballonets is kept inflated all night, which do you consider best, keep ballonets inflated or not inflated?

A. It is considered that the purity of the gas in the bag at all times is of more importance than the cost of the gas required to keep the bag properly inflated. Therefore, if possible I would not keep the ballonets inflated with air, because the air penetrating from the ballonets into the gas bag would considerably reduce the purity of the gas, thereby necessitating the purging of the gas bag more often and at greater expense than it would cost to keep the pressure up by inflating the main bag with gas.

Q. How are the seams secured together in a balloon?

A. The seams of a balloon are lap-jointed, cemented, double stitched and taped inside and out. The seams are usually $\frac{1}{2}$ inch to $\frac{3}{4}$ inch lap with two rows of stitching $\frac{1}{4}$ inch apart, 7 or 8 stitches to the inch. The shuttle stitch is used. One single ply fabric strip $1\frac{1}{8}$ inch wide of same color as exterior of envelope is cemented over extension of seam and one single ply raw white linen strip $1\frac{1}{8}$ inch wide is cemented over interior seam. The strip is coated with unvulcalnized rubber on the side next the seam, and over this is cemented another strip of single ply fabric $1\frac{1}{2}$ inches wide. This is rubberized on the gas side. In kite balloons the seam lap is only $\frac{1}{4}$ inch.

CHAPTER XXXIX

Method of Folding Balloons, Kites and Airships

Q. Describe the methods of folding free balloons, kites and airships.

A. *Free Balloon—Folding Up for Storage.* The balloon is pulled out straight with the valve hole at one end and the appendix at the other. The seam containing the rip panel slit is laid out straight on the ground and the rip panel in place, if the balloon has been ripped. Each panel is folded in the middle and the meridian seams laid on top of one another. The entire balloon now lies on the ground in a long strip and tapering to the valve hole at one end and the appendix at the other, resembling a flattened orange peel. The reason for placing the rip panel in this location is to facilitate repairs. For a similar reason in wrapping up this long strip the start is made at the appendix and the valve hole and rip panel is rolled on the outside of the bundle. Thus, it is necessary to unroll and unfold but a small portion of the balloon for the insertion of the rip panel. The balloon is now rolled in its packing case and placed in the basket, everything having been previously removed from the basket, also valve and any other movable wood or metal parts which may damage the balloon fabric when wrapping it for storage.

Kite Balloon. Fold a kiteballoon after the removal of detachable parts as above mentioned for free balloon, and wrapping all fixed metal parts such as steel wire, cables, etc., in a canvas or old rag covering to protect the fabric, first greasing the parts to prevent rust and deterioration. In some cases bags are furnished in which many parts attached to the envelope can be placed and same rolled up in the main bag,

while others are placed separately in the trunks furnished for the complete balloon. The car or basket suspension made of hemp and fitted to the belly band can and should be removed from the envelope before folding for storage for any length of time, as mildew may occur and rot the cordage and damage the fabric. Also see that all fabric is clean, dry and cool when folding. · Never fold in sun if it can be avoided.

Airships. In folding an airship: The car having been disconnected and the rudder, fins, elevators, nose battens, valves, scoops, gravity tanks, in fact all movable wood and metal parts as well as suspension cables, bridles and control wires, and those not removable inside and out have been properly greased and wrapped with burlap, cotton cloth or canvas to protect the fabric; the balloon is then laid out as before mentioned, the nose at one end and the tail at the other; the fabric is folded in a long strip one section wide and the full length; if possible, let the envelope lie for three or four hours and much of the gas or air which was not driven out up to this point will slowly work itself out. The cables or ropes which were not detached, owing to their being spliced permanently into the finger patches, are laid out smoothly between the folds the long way, so that they will fold or roll up without injury to the fabric. When the envelope has settled down due to the escape of the air through the various openings, start rolling the bag from the nose to the tail, forcing out all remaining gas through the appendix in the tail. Put on cover and store in the trunk for same, and put same in dry, cool, dark place. If such a place can be had, and is large enough to permit of storing the envelope in one long strip wrapped in the ground cloth for same without the rolling, it is believed the life of the fabric would thus be prolonged, as folding and rolling airships that have been doped is cause for cracking and breaking of the dope film, necessitating redoping before the airship envelope will give satisfaction.

CHAPTER XL

Structural Inspection

Q. What inspection would you make from a structural standpoint before pronouncing any of these balloons ready to take the air?

A. Before pronouncing a free balloon ready to take the air: Examine thoroughly all parts, wood, metal, rope and fabric; the net with its crows feet suspension to the suspension ring; the basket (car) structurally, also main suspension ropes that pass through and under the fibers up to the suspension ring; toggles and eye splicing as well as the harness cord wrapping over some or most of these splices; the gas valve, ring, seat, gasket, springs, yoke, etc., the valve cord, the rip panel and cord, the appendix ring, appendix draw string and valve cords properly measured off and arranged handy for operator. See that the basket is attached to the car with the long side under the rip panel; attach basket to suspension ring so that drag rope will be on the proper side. Balloon should be fully inflated.

Kite balloon should be given a similar inspection as given the free balloon with a further inspection as follows: Inspect set and test gas valves, gas valve to open automatically when ballonet is empty and gas pressure 1.6 inches according to manometer. Examine lobes and lacing and openings between them to ballonet, air scoop to ballonet, winch suspension V wires, rigging band (belly band) and finger patches, handling wires and the cable to the winch which is to let the kite balloon out and hold or haul it down as desired, also the telephone cable which is in the center of the kite cable and its connection to the kite basket set and the winch. Should the

balloon not balance properly the proper balance can be obtained by means of changing the fore and aft suspension until the balloon rides at the desired angle.

Inspection of an airship: Check the alignment of the car with the fore and aft axis of the balloon by dropping a line from the nose and one from the tail. Mark the center of buoyancy on the car from blueprint and check distance from nose. Check the distance from top of car to bottom of balloon which should be as called for on plans. Examine all ropes, wires and cables for soundness as well as fittings, turnbuckles, shackles, rings, thimbles and eye splices. With 1 inch pressure in gas bag note whether there is any tendency to buckle or droop. This may be due to undue stress on the fore and aft suspension. Examine rudder and elevator for clearance from the bag and freeness, smoothness and positiveness of action, and that with 1 inch pressure in the bag, the controls to be reasonably taut. Examine all finger patches; see that they are in good condition and the pull on each is evenly distributed. Examine, set, and test the air and gas valves. Gas valves should start to open automatically at 1.6 inches as shown on the manometer, the air valves at 1.3 inches, when the gas pressure in the main envelope is to be carried as 1 inch. Examine the ballast tanks and valves, also cords to same. Examine the nose battens and fins, fin braces, and see that the fins lie on center line of patches except lower vertical fin which is offset to overcome torque on a pusher type ship. The longer wire of each pair of braces should be put above the side fin so as to give the fins a droop of 2 to 3 inches at outside edge. See that the V-wire on bridle and connections of the drag rope are in perfect condition. All pulley leads and wire where it passes over them should be examined. See that all metallic parts that come nearer than six feet to each other are electrically connected. Balloon full of pure gas properly balanced should trim on an even keel

with the power off and a full load in place. See that there is at least a two inch take up in the rudder wire reels on the rear foot bar. See that dampers work and are tight, alsothat scoops can be raised or lowered. The pontoons inflaed and properly secured in place; all instruments in place and securely fastened; the car frame wires and fittings inspected for soundness, rigidity. See that sea anchor and cable are in good condition and the cable properly made fast in the nose and led aft to the car and secured.

Q. What factor of safety has an airship when the manometer tube reads $1\frac{1}{4}$ inches?

A. When the manometer tube reads 1 to $1\frac{1}{4}$ inches the usual safety factor is about 8 if envelope is new.

Q. What is the weight of hydrogen gas and air?

A. Hydrogen gas weighs approximately 5 pounds per 1000 cubic feet and air approximately 75 pounds per 1000 cubic feet. Weight of one cubic foot of air at 30 inches pressure (Mercury) and 70°F. 0.075. Weight of one cubic foot of hydrogen gas at 30 inch pressure 70°F. 0.005.

Q. What rule is there for determining the length of a drag rope of a free balloon, kite balloon and airship?

A. The method for determining the length of a drag rope is to multiply the diameter of the balloon by 5 and add 60 feet to this. This is approximate.

Q. What is an appendix, and for what purpose is it used on the three types of balloons above mentioned?

A. The appendix of a free balloon is a tube or alcove made of rubberized fabric, its length and diameter being in accord with the size or volume of the balloon. A 19,000 cubic foot free balloon has an appendix about 15 inches in diameter and

about $5\frac{1}{2}$ feet long. A kite balloon is fitted with the appendix in the bow just below the nose. It is large enough to permit men to enter the bag. It is also fitted with an inflation tube which after inflating the bag can be rolled or folded and placed in a pocket about the appendix, and the flap buttoned down. The tube is securely tied with a rubber cord or tape around a rubber core to prevent gas escape. An airship is fitted with two appendixes, one underneath and just forward of the after ballonet about opposite center of the car, and the other under the tail of the balloon. Used for entering balloon for work or inspection, also for inflation purposes. Made of rubberized fabric reinforced at junction of envelope, and taped over all joints. In addition to the appendix above mentioned for a free balloon, kite balloon and airship, there are fitted other and smaller appendixes for the various valve cords, rip panel cord, etc. These are cemented and originally sewed to the bag and taped at joints, fitted with rubber cores through which the cores pass and afterwards taped to prevent leaks. And in a kite balloon the rear appendix in some types is led in through the vertical lobe to the tail of the balloon for inflating the upper lobes. In a free balloon the appendix is located at the opposite side of the bag from the valve, which in the case of free balloon is the bottom; kite balloon nose and tail; airship bottom about one-third distance from nose and under the tail of the bag aft of the rudder. On airships appendixes are called inflation sleeve. The principal use of the appendix in a free balloon is to permit equalizing the pressure inside and outside the balloon, and its length prevents air getting into the bag and gas getting out except by expansion and contraction. The length is also governed by the strength of the fabric of the balloon.

Q. Which do you consider the best ballast, sand or water? Why?

A. Water, if the equipment is such that the water ballast can be released in sufficiently large quantity to be of service in checking the descent, otherwise sand.

Q. What special inspection would you make in connection with the rudder on an airship?

A. The rudder in addition to the inspection for soundness of its members should be examined for clearance of the bag, free and smooth as well as positive movement, that the hinges, pins, horns and braces are in perfect condition and that the rudder control cables should have no sag in them.

Q. Describe static electricity, and how it is induced in a balloon.

A. Causes of sparks which ignite the hydrogen seem very obscure, although there are various theories put forward. The passing of dry gas over metal surfaces does in some cases cause the metal to become charged with electricity, and at times a fairly large spark can be obtained by bringing two such objects together. Compressed hydrogen is dry and it seems possible that the valves of the flasks become charged, due to the rapidity with which the gas passes through them, so that if the tube is blown suddenly off the valve, a spark may occur which would ignite the hydrogen. It is also believed that a person's body may, in dry weather, become so charged that when coming in contact with another body or the valve or any part of a balloon so charged, cause a spark, and if valving a balloon may, if closer than 6 feet, be the cause of an explosion and perhaps the destruction of the balloon. It is also stated that it is possible to cause this spark by rubbing the inflation hose or tube, or the balloon itself, in taking it into or from the hangar, both being charged. An airship may become highly charged while passing through

the air at a high speed, especially if there are particles of dust, smoke or mist; with ordinary air the effect is small with vessels with a speed below 60 miles per hour. The hydrogen gas may issue from a valve with sufficient speed when gassing to charge the rubber gasket of the valve seat and cause a spark to pass through the gas to the valve. This, however, may be prevented by coating the rubber ring with graphite or by connecting the valve and the seat by a wire fastened to each.

Q. Describe a kite balloon winch, and what is necessary for its upkeep?

A. There are three types of N. C. L. kite balloon winches, in all three of which the cable handling mechanisms are similar but which differ primarily in their form of power plant, viz: (1) gas engine used chiefly for shore stations and motor trucks; (2) steam engine for destroyer service; (3) an electric motor used mainly for battleships. The N. C. L. Engineering Corporation of Providence, R. I., furnishing the gas engine type for shore stations and battleships. The gas engine types are equipped with 8 cylinder Herschell-Spillman motors which drive the winch unit through Entz magnetic transmission. The electric types are equipped with motors of the General Electric Company's "CO-1800" line, are of the totally enclosed series wound type and have an intermitter rating of 50 horse power at 725 R. P. M., based on a 55°C. temperature use. Requirements: Shall be capable of exerting a maximum pull of 6000 pounds on balloon cable. Haul in at a maximum speed of 400 feet per minute against a 2000 pound pull on cable. Haul in at a reduced speed at any pull of 2000 to 6000 pounds. Pay out, maximum speed of 1000 feet per minute. Pay out at a speed of not more than 150 feet per minute against a dynamic breaking effect with a pull of 2000 pounds on cable. Smooth stopping and start-

ing must be obtained under all conditions of load and speed.

The functions of a kite balloon winch are: Hauling down the balloon, paying out the cable when the balloon is ascending and holding it when it is aloft. The cable serves two purposes—it holds the balloon and carries the inner core of an electric telephone cable, whereby communication can be carried on between the kite and the ground or ship. Care must be taken not to kink or make sharp angle turns with this sort of cable, as the telephone cable may be destroyed. There is a main drum which carries the $\frac{3}{8}$ inch cable generally used. This type of cable should never be reeled up under a great strain, and to prevent this a system of two surge drums with one, two, three and even four additional single sheaves is used, the drums and sheaves being grooved deep enough to carry the cable with little chance of it jumping out of the grooves. The main drum (called storage drum) is located on the frame or base of the winch and in front of the engine, the surge drums on the left hand side of the storage drum and engine and directly connected so that these drums take the load coming on the cable and gradually reduce it until when it reaches the storage drum there is only sufficient pull on the cable to make it lay in smooth coils about the drum. There is also a leading swivel block directly in front of the surge drum with two sheaves over which the cable passes before it reaches the surge drum. This swivel block with one sheave in each end of it serves to keep the cable in control at all times, no matter which way the kite may be from the winch. When the cable leaves the surge drum it passes around a large horizontal sheave directly under the lower surge drum to another sheave, running with its axis the same as the large storage drum and which works back and forth on its axis, thus regulating the coils of the cable on the storage drum under a light tension. The two surge drums are about 12 to 14 inches apart and the center of the axis of

the two drums are on a line about 60 degrees from the base of the winch. The operator stands or sits directly in rear of the surge drum, feet on pedals and hands on levers, facing the surge drums. There is a graduated cable indicator which gives the number of feet of cable paid out attached, also a tension indicator for registering the pull in pounds on the cable while the kite is in the air or being held near the ground. The care and upkeep of a kite balloon winch is similar to that exercised on board ship for steam and electric winches and cranes.

Q. How is communication maintained with a kite balloon?

A. By making the necessary telephone connection at the winch end of the cable, which has an electrical telephone cable as its center core, and the kite end of this same cable.

Q. What would be the percentage of diffusion of gas in twenty-four hours that would warrant the re-doping of the envelope?

A. As the diffusion of a new bag is about 0.2 of 1 per cent in twenty-four hours, it is believed that a diffusion of 5 to 10 per cent in twenty-four hours is sufficient reason for redoping the envelope.

Q. What should be the maximum permeability of balloon fabric?

A. The maximum permeability per square meter for twenty-four hours on new balloon fabric should not exceed, for three-ply envelope balloon fabric as used for C and D class airships, 15 liters.

This maximum permeability applies also for airship fabric used for ballonets, two-ply, in B, C and D class airships and R and M type kite balloons.

Q. What is the difference in the weight of a cubic foot of water and a cubic foot of sand?

A. A cubic foot of fresh water weighs 62.5 pounds, salt water 64 pounds, dry sand about 103 pounds. Difference about 40 pounds per cubic foot.

Q. What is the usual weight of a bag of sand ballast?

A. The usual weight of a bag of sand as used in connection with balloon work for ballast purposes is 30 pounds.

Q. What are the dimensions and of what material is a sand ballast bag made?

A. Sand bags are made up of about No. 6 canvas. Lap seams and double stitched, with a 1 inch strap on the bottom. The bag is 9 inches in diameter and about 12 inches high from bottom seam to center of eyelets, there being eight eyelets spaced around the top hem for the purpose of reeving a draw cord to close the bags when filled with 30 pounds of sand, also for the purpose of suspending the bag to the net or other parts of the balloon when inflating.

Q. By what means are side valves in a kite balloon or an airship operated automatically?

A. The side valves in a kite balloon and airship are usually of an automatic type, which can be set to open at a desired pressure from within the bag by the means of an adjusting gear connected with the mechanism of the valve. This is especially so in the case of a gammeter valve, which is the type of valve used at present in all but free balloons. In some of the older type kite balloons a system of cord connection from the valve in the nose of the balloon to a patch in the tail, with a vertical cord from this down to a spider of eight cords each, anchored to a patch cemented to the diaphragm of the ballonet and connecting at a point representing the apex of a cone. The cord is so adjusted that when the balloon is nearly completely inflated with gas,

the ballonet becoming flattened out against the envelope and the pressure of the expanding gas causes the balloon to increase slightly in diameter; this combined effect puts a tension on the cord and opens the valve allowing the gas to escape until the pressure is normal when it automatically closes as the tension on the cord decreases. Forward opening star valves are also used on kite balloons, M type.

Q. What is the nearest distance a person smoking would be permitted in the vicinity of an inflated balloon?

A. When a balloon is being inflated, no smoking, open fires or lights should be permitted within 150 feet, and no open fires should be permitted in vicinity of a balloon when inflating.

Q. What is a hydrogen flask and of what material is it manufactured?

A. A hydrogen flask is a cylindrical seamless steel container, 8 inches inside diameter and 4 feet and 3 inches high without valve or cap. Made of steel conforming to specification No. 3A and Navy Department specification No. 65C10a, February 1, 1918. Chemical analysis carbon 0.55, phosphorous 0.04, sulphur 0.05. Physical: elongation not less than 10 per cent on 8 inches test specimen. Elastic limit not more than 70 per cent of the tensile strength. The bottom is slightly concaved, the top drawn to a neck and fitted with a malleable iron neck ring and threaded (outside) for a $3\frac{1}{2}$ inch diameter cap, and inside with a $\frac{3}{4}$-inch pipe tap, 14 threads to the inch, with a $\frac{3}{4}$-inch taper per foot. This neck ring is stamped with the name of the bureau concerned. Each container is fitted with a controlling valve of a type approved by the bureau concerned. The valve has a $\frac{5}{32}$ inch outlet at right angles to the vertical axis of the valve, and is threaded with a special machine thread 14 threads per inch. Outlet threads

of hydrogen shall be left hand 0.830 inch O.D. The walls of the cylinder are 0.23 inch. Capacity 2600 to 2700 cubic inches weight 110 to 120 pounds without valve or cap. Cap weighs 3 pounds, valve about 1 pound. Valve is also fitted with a suitable safety device (disc) which will rupture at 2500 to 3000 pounds per square inch, tested by the Bureau of Explosives.

Q. How many cubic feet of hydrogen are contained in this flask and what is the weight of flask and hydrogen combined?

A. A hydrogen flask contains from 180 to 200 cubic feet of hydrogen gas when charged under a 1800 pounds pressure. The weight of the container is from 110 to 120 pounds. It is impracticable to tell whether a container has gas or not by weight as hydrogen gas only weighs 0.005 per cubic foot and 200 cubic feet would only be one pound.

Q. How is hydrogen put in the flask at the place of manufacture?

A. Hydrogen is put in flasks at place of manufacture by means of compressors. The flasks are connected up to a manifold and the compressor takes the gas from the holder and drives it into the flasks under a pressure of 1800 pounds per square inch.

Q. Is the purity of the gas lowered by putting same in a flask?

A. The purity of the gas is not lowered by putting it in flasks if the following precautions are taken: First open valve of flask slightly to see if same is empty, if not, recharge, if empty. Connect up and charge to 200 to 250 pounds, then disconnect and allow the flask to empty; connect up again and repeat the operation, being careful to close the valve immediately the flask is empty, which is when it almost stops

escaping through the valve. Close valve and connect up for the final charge which is 1800 pounds.

Q. What color paint is marked on a flask to designate that it contains hydrogen?

A. Hydrogen flasks are painted black and have a white band 6 inches wide painted around the flask, the top edge 18 inches from the neck ring.

Q. How much pressure will a hydrogen flask withstand without rupture?

A. Each hydrogen flask is subjected to an internal test of 3000 pounds per square inch. One of each lot of five hundred or less are tested to the bursting point, and they are not supposed to burst under 6000 pounds per square inch. The safety device fitted to the valve on hydrogen flask is supposed to relieve the pressure and allow the gas to escape, preventing explosions due to expansion of the gas in cases where cylinders are in a fire.

Q. How many types of manifolds are used in connection with transfer of gas from flasks to balloons, and which is most generally used?

A. There are two types of manifolds: (a) low pressure and (b) high pressure. The low pressure manifold is most commonly used. The low pressure manifold consists of a cylinder made of a section of pipe $5\frac{1}{2}$ inches outside diameter, $\frac{3}{16}$ inch walls and 14 inches long. Screwed into the bottom are 10 nipples with 8-foot armored hose connections attached. Each hose is fitted with a cap nut which is provided in case fewer than 10 flasks are connected at a time.

Q. What precautions should be taken when inflating from flasks or recharging empty cylinders with hydrogen gas?

A. In connecting cylinders to a manifold for the purpose of inflation or for the purpose of compressing gas into the cylinder it is absolutely essential to the preservation of life and property that if the gas in question be hydrogen, cylinders containing any other gas be kept out from the manifold. If hydrogen is compressed with certain gases a violent explosion will occur. If in connecting up the manifold the gas in any of the cylinders is questionable, do not use the cylinder as it might contain a gas that will cause an explosion. Also be very careful to see that washers that are non-conductors of electricity are not used to make an air tight valve connection on the cylinder or the manifold. Static electricity is produced by the friction of gas rushing through small openings, such as is found on the ordinary cylinder valve. If a non-conductive washer is used, the circuit to the ground is broken and a fire will occur. Also be sure that the cylinder is placed on a substance that is a conductor of electricity, for if it is not grounded the static produced by friction will have no escape and the result will be disastrous.

Q. When a cylinder full of compressed hydrogen is insulated and the gas is blown out through a copper tube, may the cylinder become charged? If so, how does the effect depend upon the rate of discharge? Does the charge increase uniformly with time?

A. Yes, it increases rapidly with the rate. Marked effects were obtained when the gas was discharged through a copper tube $\frac{3}{16}$ inch in diameter, at the rate of 4 cubic feet per minute. No, the charge does not increase uniformly with time.

Q. Is a brush discharge as effective as a spark in exploding mixtures of hydrogen and air?

A. It is believed that the discharge from the brushes of the wireless equipment is not as effective as the spark.

Q. Is the balloon fabric used in the manufacture of airships a good insulator or not?

A. Rubberized cotton fabrics such as are used by the Goodyear and Goodrich Rubber Companies are sufficiently good conductors, even when thoroughly dry, practically to equalize the potential of the whole balloon surface in about a minute.

Q. Are the hemp ropes used in suspending the fuselage good insulators?

A. No. From an electrostatic point of view they are good conductors when wet.

Q. Are the rubber rings forming part of the Goodyear valve seat good insulators?

A. Yes, when they are clean.

Q. May an airship acquire an electric charge as a result of being driven through the air at high speed?

A. Yes, if the speed is sufficiently great; rubberized cotton fabric becomes negatively charged while rubberized silk fabric becomes positively charged. Rubber when rubbed against cotton, silk or aluminum becomes highly negatively electrified.

Q. What is meant by the term "lift" as used in connection with balloons?

A. By the term "lift" is meant the difference between the weight of the balloon (including gas) and the weight of the supporting medium displaced, which is air. Lift is affected by the volume of the gas in the balloon, the purity of the

gas, the barometric pressure of the air, the temperature of the air, and the humidity of the air. Quite naturally, the more gas the balloon contains the greater will be the positive lift. This is one reason for always having the balloon as completely inflated as possible, when at its working altitude. Lift as applied to kite balloons should be specified as to whether it is gross lift or useful lift. The gross lift is the total displacement of the balloon minus the weight of gas. The useful lift is the difference between the gross lift and the fixed weight of the balloon; while in an airship the gross weight includes the weight of the gas.

Q. What is a leak detector, and for what is it used?

A. A leak detector is an instrument used in locating leaks around valves and other openings in a balloon as well as the seams and the fabric itself. This instrument consists of a perforated nickeled plate mounted on a hardwood ring about 8 inches in diameter, with a disc made of a specially prepared clay or some other composition, placed back of the perforated plate, a delicate diaphragm with a movable hand which indicates a leak, but does not register the quantity of the leak. The hand indicating a leak will remain at the position to which it is forced by the leak until released by the opening of a small press valve. Very slight leaks can be detected when the instrument is carefully placed with the hardwood ring at the back against the fabric, so that the pressure of the leak will reach the disc. Only hydrogen gas will pass through this disc. The leak detector is made in two or more sizes. The 4-inch and 8-inch sizes are in use at Pensacola, Fla.

Q. What is a mooring harness, and where and on what types of balloons is it used? Of what is it made?

A. Mooring harness is fitted at the top of a kite balloon and is used to anchor the balloon, also for bagging down.

This harness is made of heavy braided cotton tape securely cemented to the envelope in a zigzag manner along the first and second gores from the center line and practically the full length of the bag, and held by patches, and is covered over with a light fabric tape matching that of the envelope. To this harness sixteen picket lines are attached by means of drop forged steel rings. There are seven lines on each side, one on the nose and one at the tail, made of the best grade manila or Italian hemp, and are used for anchoring the balloon to the ground in windy weather. The ends of the lines are fitted with eyes for reeving the anchor lines through.

Q. What is a junction piece and where is it used? In connection with what type of balloons?

A. A junction piece consists of a piece of stranded wire cable running through two U-shaped hollow steel tubes and having an eye or loop spliced in one end and a brass toggle spliced into the other. It is used as a quick means for connecting or disconnecting the metallic V-wires of a kite balloon from the main cable leading to the winch. The main cable is attached to the junction piece by means of a loop in the end of it, which is slipped over one of the U tubes in the junction piece. The toggle in the junction piece is then put through the loop in the other end and the complete connection is made. The above description covers the R type kite balloon.

Q. What are furling ropes and to what are they attached in a kite balloon?

A. Furling ropes are attached to the two side lobes of a kite balloon, four ropes to each, and are used for the purpose of deflating and furling the lobes when so desired in manœuvering or anchoring the balloon.

Q. In what way does the mid-suspension differ from the forward and rear suspension in a kite balloon?

A. The mid-suspension of a kite balloon differs from the forward and rear suspension in that it contains an adjusting block and shock absorber. The adjusting block is used to make the mid-suspension taut when the front and rear suspensions have been attached and the basket located where desired. The shock absorber tends to take up any sudden jerks due to swaying or nose dives.

Q. Name some of the knots used in connection with the ropes and rigging of a kite balloon.

A. Some of the knots and bends used in connection with rigging of a kite balloon are: Figure eight, reef, clove hitch, single and double sheet bend, Mans harness hitch, sheep shank, bowline, bowline on a bight, crown knot, lever hitch, timber hitch, picketing hitch, eye splice, and the thumb knot.

Q. What are pickets, and for what are they used?

A. Pickets are mild steel or iron stakes with an eye in the top end. The bottom is pointed with two spurs or screw wings which assist in keeping the stake in the ground. In a way a picket is similar to an auger but has only two wings. They come in various sizes and lengths from 18 inches up to 4 or 5 feet, used in mooring a balloon down to the ground.

Q. How does helium gas compare with hydrogen gas, first, as to weight; second, as to lifting power; third, as to ignition from sparks from atmospheric electricity and radio, and fourth, as to cost of production?

A. Helium gas weighs approximately 6 pounds per 1000 cubic feet; hydrogen gas weighs approximately 5 pounds per 1000 cubic feet. Helium has a lifting power of approximately

92 per cent of hydrogen or 64 pounds per 1000 cubic feet, and hydrogen 70 pounds per 1000 cubic feet. Helium is a non-inflammable gas, while hydrogen is dangerously explosive when mixed with air, in certain proportions. Hydrogen can be manufactured at a cost of from 5 to 10 dollars per 1000 cubic feet, while helium at present costs from $55.00 to $60.00 per 1000 cubic feet to produce.

Q. What is goldbeater's skin and for what is it used?

A. A goldbeater's skin is the blind gut of an ox, and is used in lining fabric for gas bags of a rigid airship. A gold beater's skin is practically impermeable to hydrogen, but owing to the small area (about 8 inches square) of each skin, it is a very expensive material for this purpose.

Q. What advantage has the airship over the airplane?

A. The main characteristics of an airship are: (1) long endurance, (2) ability to carry heavy loads, (3) variation of speed, (4) reliability, by which is meant freedom from liability to mechanical breakdown during flight, (5) comfort, (6) security. An airship need not descend in unfavorable country even if the engine fails while the airplane must descend. The airplane, on the other hand, bases its claims on the following points: (1) high speed, (2) low cost of production as compared to airships, and maintenance, (3) ease of housing.

Q. Describe in detail how you would prepare a parachute for use on a balloon about to make a flight?

A. The parachute is laid out on the ground cloth preparatory to folding for packing in a container made of fabric and cone shaped, with a ring in the inside of the top to which the parachute is made fast with a 30-pound breakable cord. There is also an eye on the outside of the top for securing the container to the car or basket. In folding the parachute for

packing it is flattened out on the ground cloth the width of two pleats, so that there is one cord at each edge and one in the center. Then take every other cord in hand allowing the one skipped to fold down between those taken in hand until you have an equal number of pleats on each side of the flattened section. Lay these folds down flat and straight on top so that you will have another full width section on top when complete. These two outer folds form a pocket which it is stated seems to catch the wind and cause the parachute to open quickly when released from the container. Set the container bottom up and secure the top of parachute to the ring, with the breakable cord mentioned, and fold or pack the parachute into the container by a series of accordion pleats; then continue with the cords coiling them in a clover-leaf coil, arranged so that any two coils of cords running in the same direction have a coil of cords running in another direction between them. Level off the top of the coil so that the suspension hoop will lay flat on top, and then secure it in place with four breakable cords which are made fast to the inside of the container. The four suspension ropes from the hoop are then coiled down on top of the hoop and the cover through which the suspension ropes lead is put in place and securely held by an elastic band around the edge. The junction of the four suspension ropes and the central rope to the toggle in the cover are close up to the cover and only the main suspension rope with hook in the end for attaching to the harness is left free. The parachute is now ready for attaching to the car or basket.

Note: The above mentioned description applies to the general type of parachute carried in containers in airships. There may be a slight variation from the above description in some special type parachute or some special precautions necessary to be taken, but as a general rule the above description covers the method of parachute packing in practically all cases where same is carried in a cone shaped container.

Q. An airship is flattened out on the floor of the hangar for inflation. State in detail what precautions you would take with the vertical fin (upper stabilizer) and the horizontal stabilizer to keep them in place and prevent damage to the bag, the parts mentioned being strapped in place to the bag.

A. The balloon being in a hangar and facilities available, a small tackle is rigged directly over the vertical fin and a bridle of six legs, two to the vertical fin and two to each horizontal fin, are led out and made fast to canvas straps placed about the fins so that they are balanced laterally and vertically. The forward leg to the vertical fin should be about 30 to 36 inches shorter than the rear leg in order that the forward end of the fin may be raised off of the floor ahead of the rear end as the bag fills with gas. The two legs to each horizontal fin should be about 3 to 4 feet longer than the rear leg of the vertical fin, as these parts are located on the bag at a point considerably lower than the vertical fin. The bridles should be made fast at the tackle so that there would be no slipping or surging, and any slight adjustment found necessary as these parts are lifted with the inflation of the bag can be made from a ladder at the bands about the fins. The brace wires to the fins are rove off with sufficient slack in them and set up later when the bag is fully inflated.

Q. Are the wire cable controls to all valves on an airship connected direct to the metal part of the valves?

A. No, the cables are made fast to a short piece of sennit line, which in turn is made fast to the valve. Also an elastic section about 16 to 18 inches long is secured to the valve cord in such a manner as to leave about 4 inches of slack in the control cable at the valve. This allows for tension on cable, due to expansion or stretch of the gas bag, without opening the valve prematurely.

Q. Describe in general details the difference in the kite balloons of the M and R types.

A. The M and R types of kite balloons are practically the same in appearance, but differ as follows: The M type balloon (similar to the British type M) is of 32,800 cubic feet capacity, a length of 82 feet, and a maximum diameter of 26 feet, and a ballonet capacity of 9358 cubic feet or 28½ per cent of the volume of the envelope, and is placed in the after part of the envelope instead of forward as in the R type, and the air enters the ballonet through an opening communicating with the rudder instead of through a scoop forward, as in the R type. The M rides at an angle of 8° to 12°, the R 3° to 4° from the horizontal. The suspension band is made up of one ply of canvas duck and several plies of envelope fabric to which are cemented and sewed individual patches for each suspension point. The patches are made of one-inch herring bone tape, which has an ultimate strength of 300 pounds. Rope used in all rigging is of Italian hemp, and a movable or self adjustable rigging is provided by means of the aluminum pulley blocks used in the bridles. Due to the greater strength (50 per cent) in the Italian hemp over the Manila Yacht rope used in the R type rigging, the rigging of the M type has a safety factor of 18 or three times greater than that of the R type. The side gas valve in the M type is automatically operated by internal rigging, the valve being opened when the diaphragm of the ballonet is down to the lowest point, the ballonet being empty and the gas pressure rising. The R type balloon is of 37,500 cubic feet capacity, a length of 92 feet, maximum diameter of 27 feet, the ballonet capacity 25 to 30 per cent approximate. The R type has a useful lift of 1229 pounds for pilots, instruments, cable and ballast, and that of the M type about 1084 pounds. The R type rigging is made of Manila hemp and not self adjustable as that of the M and the side gas valve

is of the gammeter type, automatic without the internal rigging; the maximum altitude attainable (feet) R 6000, M 5000, working altitude R 4000, M 2500. It is believed the above figures are excessive, although claimed.

Q. What is the stabilizer rigging of a kite balloon?

A. The rigging inside the stabilizer by means of which the stabilizers are kept in their proper shape, consists of a series of two diagonally crossing lines and one horizontal line attached to the envelope and stabilizer by means of fabric suspension bands and suspension patches placed at intervals and permit of ready adjustment on assembly or after flight. The diagonal crossing lines are staggered to prevent chafing.

Q. What is a suspension bar?

A. A suspension bar used in kite balloon rigging is a horizontal bar made of ash or some other equally strong wood, to which are attached the "fore," "mid" and "aft" basket suspension lines, also six lines for attaching the bar to the basket.

Q. What is a nurse tube and where located in a balloon?

A. An auxiliary inflation tube entering the envelope at its lowest element just forward of the toe of the ballonet and extending along the outside and bottom of the envelope and thence to the basket. It is used in inflating (replenishing gas) from aboard ship when the balloon is in the air, thus avoiding the necessity of having to haul the balloon down on deck completely for the inflation through the appendix in the nose of the balloon.

Q. What is a quick attachment coupling and where is it used?

A. The quick coupling is fitted to the basket end of the nurse tube which is connected to the main inflation line on

board ship. It is made of bronze and is somewhat similar in construction to a fire hose coupling. The female end is permanently attached to the basket end of the nurse tube and the male end, provided with a metal sleeve 5 inches long, is kept on board ship available for attachment to the main gas inflation tube. The quick release or attachment coupling provides a means for reducing the time required for making connections during the inflation of the balloon through the nurse tube. The rubber gasket seat between the male and female parts forms a gas tight connection.

Q. What is a check valve, how made and where used in a kite balloon?

A. A check valve is located at the envelope end of the nurse tube and provides a means for automatically closing the inflation tube at the envelope after inflation. It consists of a 90-degree elbow made of aluminum with an open end outside the envelope for the attachment of the fabric nurse tube and a closed end inside the envelope. This closed end has a number of 1-inch diameter holes through it. A rubber elastic sleeve encloses the discharge end of the valve. During inflation this elastic sleeve expands and allows the gas to flow into the gas bag. After inflation the sleeve contracts and covers the holes, and thus checks the back flow of gas. This also eliminates considerable diffusion which would occur with the valve at the basket end of the nurse tube.

Q. What is a discharge tube or hood and where is it located in a kite balloon?

A. When the gas leaves the check valve at the envelope end of the nurse tube, it discharges into a loose fabric hood or tube which encloses the entire check valve and extends about 6 feet forward of the valve, is cemented to the envelope,

and has about eight 3-inch diameter holes for allowing the gas to flow into the envelope. During inflation the gas pressure holds the fabric up to full form and allows the gas to discharge freely into the bag, and after the inflation ceases this hood collapses and the discharge holes are closed, thus forming a second check against backward flow of gas through the nurse tube.

Q. What instruments are carried in a kite balloon?

A. The instruments carried in a kite balloon are: Gas manometer, compass, anemometer, altimeter, binoculars, watch, telephone, and in addition to these pencil and paper for notes, also charts and maps.

Q. What is the maximum pull on a kite balloon cable, also what is the breaking strain?

A. The breaking strain of a $\frac{3}{8}$ inch diameter 7 by 19 stranded steel wire cable as used for kite balloons is 14,000 pounds, and the maximum strain on it when balloon is in flight, even in a 60-mile per hour wind, is only about 6000 pounds.

Q. What are danger cones and for what purpose are they used?

A. Danger cones consist of a small cone made up of fabric with a lanyard about 3 feet in length connected thereto. These cones are snap hooked about 300 feet apart on a kite balloon cable in order to warn heavier-than-air craft to keep clear of cable. The first cone, however, is placed 800 feet below the balloon. Pennants are sometimes used for this purpose, but the cone is considered more desirable.

Q. By what means are airships inflated?

A. Airships are inflated through what are known as inflation appendixes, consisting of one, or generally two appen-

dixes about 30 inches in length, to which the inflation hose is attached while being inflated, after which the appendix is folded and tied off to prevent leakage and pushed inside of envelope, and the flap which is secured to envelope is laced around the opening in the envelope.

CHAPTER XLI

Instructions for Putting in Service, Rigging of Cable and Operating N. C. L. Kite Balloon Winch

The following operating instructions for N. C. L. kite balloon winch were furnished the Government by the manufacturers of this type winch.

Having installed the winch in position, the leading-off gear packed in a separate box may be assembled. First the double-tapered steel bar is inserted in the hole bored for it in the base. The keyway in the bracket should be at the outer end. A spot will be found sunk in one end of this bar and this spot should match up with the point of the set screw that will be found in the base about 14 inches directly back of the leading-off gear support boss. The leading-off gear itself is inserted in this boss and then the end bracket applied to support the outer end and both pinch screws tightened up. The stand should swing freely in this position. If any binding is encountered, it will be due to the outer boss being slightly out of alignment with the support boss on the base and correction may be made by rocking the steel bar carrying the support bracket very slightly by blows from a lead hammer. The next point in the installation of the leading-off gear is the attachment of the stabilizing spring, a stiff tension spring which will be found in the same box with the rest of the gear. The eccentric anchorage lever is provided in order to easily tension this spring. The bosses for its support are on the side of the base where the lever will be found already installed. The screw should be taken out of the small end of this lever and the lever rocked so that the pin projecting from the

pivot boss is at the nearest point to the leading-off gear. The spring is then hung on this pin and the through pin in the leading-off-gear spring bracket passed through the other eye. Cotter pins are inserted and the tensioning lever rocked back into its permanent position stretching the spring. The screw should then be inserted to lock the lever in this position.

Before an attempt is made to install a rope, the power plant should be tested for condition. In order to do this, the battery cover should first be lifted and the battery connected. Take off the starting crank bracket cap and have a man at the crank. This is probably necessary owing to the fact that the battery, having been shipped, is in a somewhat depleted condition while the engine is probably stiff owing to the same circumstance. Having the gasoline tank filled, fill the radiator, take the $\frac{1}{8}$ inch pipe plug out of the head of the Stewart vacuum tank and put about a pint of gas in this tank replacing the plug and making sure that it is tight. Look at the oil indicator on the engine. There is a vertical wire with its end bent at right angles indicating on a pressed steel scale on the crank case just ahead of the flywheel housing on the right hand side of the engine (at the point nearest the driver's seat). This should read well up to the top of the scale. In the event of oil being required, use Mobile "A" or almost any good medium engine oil. Leave the magneto lever on the dash board in advance position which is coincident with open throttle position. Open the throttle about 1 inch on the quadrant and then after throwing the ignition switch over to the start position (the word "Neutral" means nothing on this switch and should never be used as a switch position), lift the latch of the controller handle and, *with the hand brake applied to the winch*, throw the controller lever forward one notch at the same time having a man on the starting crank

give aid. As soon as the engine starts bring the controller lever back to neutral adjusting engine levers for idling position in the usual way, replace the starting crank bracket cap and after a moment or two's running to warm up, leave the hand brake in set position and throw the controller by tripping the latch forward two notches. It will be found that the ammeter on the dash now gives a charging indication and that by adjusting the throttle lever this may be regulated. Carry the charging rate at about twenty amperes and charge the battery for half to three-quarters of an hour at this rate in the meantime removing the vent plugs from the battery cells and watching for excessive gassing. If this latter condition is encountered, cut the charging rate to about ten amperes and carry the process until the hydrometer reading of the cells is 1.280. In the event of the cells seeming to have lost electrolyte, fill with distilled water and watch for gravity. As charging proceeds, it will probably be found that the battery can be fully charged in about an hour to an hour and a half and it is strongly recommended that this procedure be undertaken as soon as the winch is installed as the process of putting a rope on occasionally demands the use of the reverse gear of the winch. This latter function is accomplished from the battery.

After the battery is in condition, it is well to operate the winch in general for a few moments in order to properly lubricate the cam gear and to make sure that everything is in order. In order to run the winch, release the hand brake and with the controller handle still in the outer position, bring the handle back gradually towards the operator. It will be found that the winch speeds up and that the high speed is the position when the handle is nearest the operator's seat. In the crossover notch is neutral position and there are five points between the two that give positions

of decreased power but increased speed on the part of the machine. The notch into which the controller handle can be passed is a braking range, the maximum ability of which is on the neutral point of the controller. As the lever is drawn back towards the operator in this notch, the electric braking effect is reduced. In order to reverse the motion of the winch, the controller is moved to starting position without the hand brake being applied to the machine. For this battery driven reverse it is advisable to have motor stopped.

To recapitulate, the following are the actions necessary to induce the various functions of the winch:

To Start: Ignition switch to start position, throttle in lever on quadrant slightly forward of vertical position, ignition two-thirds from vertical position, *hand brake on winch set,* controller handle forward one notch by lifting latch. Engine having started, *controller to neutral.*

To Charge: Hand brake set, controller handle moved forward two notches by lifting latch over each notch, charging rate checked by ammeter on dash and adjusted by throttle lever to rate desired.

To Operate Winch-Haul-in Direction: Engine running, controller lever same slot as for starting. Lever moves back towards operator from neutral to high gear position. First notch gives maximum pull, minimum speed, the following notches giving increasing speed, decreasing pull. On high position, engine is running direct to winch except for slight magnetic slip. Practically all normal hauling is done with controller in high gear position, emergency conditions demanding more pull being secured by moving controller handle back. General speed of operation is entirely by engine throttle, foot pedal and hand lever as on an ordinary automobile.

To Reverse Winch: Ignition switch to off position, controller to starting position, hand brake disengaged. For

this condition, the battery is operating the transmission as an electric motor and the reverse action is only necessary when taking off cable for inspection where it is not desired to change drums. The reverse is also necessary in getting altitude with a balloon when the pull reduces itself to a point below that necessary to take cable from the machine freely. Under these conditions, the winch should be reversed until the altimeter gives the desired reading.

To Pay Out: Controller moved into the left hand slot, hand brake set, rope tensioned, release hand brake and to secure increasing speed of pay out bring controller handle towards operator. Minimum braking is at the extreme position toward operator, maximum back to neutral position.

To Reeve on Cable: Run winch until the spooling pulley, the large pulley mounted on the outside of the spooling cam, is at the outer end of its travel.

Take out the two cap screws holding guard in place by means of its split cap.

Take out the small guard wheel and the main guide sheave of the leading-off gear by turning the hand wheels and withdrawing the center pins. The hand wheels will stay with the gears and it will be found that the pins are forced out as the wheel is turned in a counter-clock-wise direction.

The side plates should be given an occasional smart rap with the hand as the pin is withdrawn so as to *eliminate binding from spring in the side plate.*

Take off the guards over the surge drums. It will only be found necessary to loosen the screws after which the guards may be rocked sufficiently to come off over the screw heads.

Arrange the cable on a stand with a detail of men at the stand and a second detail at a tensioning rig made of two planks between which the cable is drawn.

Thread the cable beneath the main pulley, through the leading-off stand boss, under the loose pulley on the inside of the lower surge drum and then by successive wraps over and under the surge drums without crossing until the last groove is filled.

Carry the cable back around the horizontal base sheave guarded by the seat support frame. It will be found that this sheave lifts vertically about ½ inch sufficient to permit the cable to be dropped into the groove.

Run the cable to the horizontal sheave at the spooling pulley; pass it around the main pulley and then over the drums leaving about an extra 12 inch of slack when a quarter wrap can be passed over the top of the drum.

Apply the spooling guard and tighten up the screws.

After making sure that the cable is slack on the surge drums start the engine and run the *winch without hauling cable* until the spooling cam rider is about ¼ inch before dead center.

Put a wire wrapping on the cable about 8 inches from the extreme end. After this is done, pass the end of the cable through the slot in the drum head. Grip it by means of the two clamps.

Cut away the steel wire of the protruding end of the rope leaving the telephone core exposed. Then strip the core and make a connection to the telephone rings by means of the small screws on the three vertical posts.

Tighten up the cable between the spooling drum and the surge drums and then by loop pulling tighten the rope over the drums themselves and so to the temporary tensioning device.

Operate the winch at a slow speed when it will be found that the cable will spool smoothly.

Each winch is shipped from the factory with a fifty tooth spooling gear installed which is usually the proper gearing

to correctly spool $\frac{3}{8}$ inch rope. There are, however, to be found among the tools in the tool box gears having forty-nine, fifty-one and fifty-two teeth. If the fifty tooth gear spools too close, remove it and install a forty-nine tooth gear. If, however, it spools too wide, it is then advisable to install the fifty-one or fifty-two tooth gears as conditions may require. The installation of these gears is easily made as they are mounted on a pivoted plate rocked into position by the pinion bolt. When the end of this bolt is loosened, it will be found that the supporting plate can be rocked forward and backward so that correct engagement can be obtained.

The instrument head contains dials, registering speed of intake and payout and amount of free cable. This latter dial can be reset to zero by unscrewing the cap at the back of the instrument housing and by turning the dial which is mounted on a light friction drive to its proper indicating mark before starting each run. This dial properly set at zero at the start of a run should return to zero when the balloon is brought down but there might be, owing to lost motion in the gearing necessary, a slight variation which can be corrected at any time. The Bristol self-recording gauge will give a permanent record of rope tension when desired. For this purpose, especially prepared smoke chart should be placed in the face of the dial and handled with great care until the desired record has been taken when the chart can be fixed by washing in the fixative which is shipped in a small can with each winch.

Except in cases of extreme emergency sudden starting and stopping of the winch should be avoided.

Always have cable at rest before starting to haul in or pay out.

CHAPTER XLII

Ballooning

FUNDAMENTALS OF OPERATION

The following is part of a course given in the above subject at the Naval Air Station, Pensacola, Fla.

A free balloon is controlled by means of gas and ballast; that is, a certain amount of reserve weight is carried called ballast which is lifted by a corresponding reserve gas. In order to ascend or to check a descending impulse, ballast is thrown overboard. To accomplish the reverse, gas is released. The latter process is largely an automatic overflow through the neck so that often the valve does not have to be used at all until a landing is to be made. It is mainly this alternate loss of gas and ballast which finally terminates a balloon flight; and the principal cause of this sacrifice is the heating of the gas and air by the sun's rays.

When the sunlight passes through any surface, a certain amount of radiant energy is transformed into heat and in the case of a balloon is imprisoned within, where it acts to raise the temperature of the gas. When the temperature reaches a certain point, enough heat is lost by outward conduction through the fabric to balance that received by radiation, and the temperature has then reached a maximum. This temperature is sometimes found in a varnished balloon to be as much as 90° F. higher than the outside air.

The temperature itself does not cause much trouble, but change in temperature does, and this is always occurring throughout the day, even in cloudy weather, from the constantly varying radiation from the sun. An increase in the temperature of course causes the gas to expand, which

drives out the air or gas which happens to be at the bottom of the balloon. Whether it is air or gas the loss of weight is like the loss of so much ballast and causes the balloon to rise. The rise is much more marked if there is air in the bottom of the balloon, and in this case it usually persists until all the air has been forced out. This is bound to occur sooner or later, however, so that a rising impulse always automatically checks itself in time.

Not so with a cooling or descending impulse, however. There is no limit to the amount of air that can be sucked in so that even a slight descending impulse may often carry a balloon clear to the ground if ballast is not thrown out to stop it. Atmospheric conditions may be generally found, however, at certain heights where the equilibrium of the balloon is essentially stable in both directions. This occurs when the temperature gradient of the air in a downward direction is less than that which would result from the adiabatic contraction of a descending particle.

It is the aim of a skillful balloonist to find these conditions and take advantage of them, and also to find wind currents which take him where he wants to go; in other words, he must use his ballast and gas in the best possible way, everything considered.

The pilot has at his service various instruments which are a great aid in attaining these ends. The recording barograph makes a record of the height above starting point, on a piece of paper. The altimeter or aneroid barograph gives the altitude above the starting point at time of reading. The statoscope tells whether he is going up or down relative to the ground. The compass tells the direction of flight.

INSTRUCTION DURING FLIGHT

In case of long flights, start the log sheet as soon as the get-away has been made, and keep a careful record of the flight. The speed and the course will be variable at first, so should be checked up every ten or fifteen minutes. A good set of maps of the country should be obtained showing the position of railroads, bridges, towns, and other prominent points. The Rand-McNally state maps are satisfactory unless more reliable maps can be obtained. Keep a careful check on the position at all times. A megaphone is of assistance in obtaining information from natives below.

Keep a watch on the air currents; this may be done by watching the clouds, by the smoke from the ground, by dropping sounding paper, but do not valve or throw sand any more than necessary at first, especially if out for an over-night or long flight, for these are the only means of staying aloft and may be of great value in selecting a landing or rather avoiding an unfavorable landing. A slow rise or fall may soon stop of its own accord and thereby save you ballast. A knowledge of the cause of these changes in altitude will be of assistance, such as a local change in temperature, a temporary increase in humidity, sun going behind a cloud, sun set or sun rise, vertical air currents, etc.

A study of the daily weather charts is most useful in making good a certain course. Surface breezes due to local causes, such as land and sea breezes, may be from quite a different direction than that due to the prevailing low or high, but such breezes usually do not extend more than 2000 feet up. You will find it a great saving in ballast to remain in the stable portion of an air current even if you have to sacrifice some speed. After nightfall and the temperature of the balloon has had time to adjust itself, you will find the atmosphere very stable and no ballast may be expended for a period of an hour or more.

In making a long flight balloon telegrams should be dropped at intervals with instructions on the envelope to be delivered as soon as possible to nearest telegraph office. These telegrams are to be sent collect to the commandant of the Aeronautic Station. State time of day, course and speed, and probable time of landing.

In making short flights from the Station for instruction, no record need be kept of course, speed, etc. These flights are made chiefly for instruction in get-away and landings, and method of changing altitudes. Notes should be kept, however, of data showing the relation of cups or pounds of ballast and valving in seconds to changes in altitude and amount of ballast, or seconds of valving to counteract a rise or fall of different speeds.

FORMULAE AND CONSTANTS FOR READY REFERENCE FOR 19,000 CUBIC FEET FREE BALLOON

1. Before the ascent

(Based on normal conditions, 30 inches barometric pressure at sea level, hydrogen gas 99 per cent pure, balloon filled to top of appendix, temperature 70° F. unless otherwise stated.)

Net lift, 900 pounds (including everything glass in the list of equipment) for 70°F. on a cloudy day.

Add 23 pounds for every 10° decrease in air temperature and from 10 to 30 pounds for varying intensities of sunlight (the greatest figure being for the brightest sunlight.)

Subtract 23 pounds for every 10° increase in the air temperature, and 5 to 15 pounds for varying clearness at night (the latter figure being for an absolutely clear day).

Resistance of balloon before start (pounds) M-1.5 v^2 where v is the wind velocity in miles per hour.

Minimum starting ballast (bags) $= \frac{v^2}{20} \tan {}^2x$ where x is the angle that the balloon has to clear and v is the wind velocity measured from the top of the obstacle.

2. During flight

(Based on an average altitude of 5000 feet, otherwise same as previous section).

Holding valve open 10 seconds to lose gas equivalent to 1 bag of ballast (30 pounds).

Unbalanced force (bags) $= \frac{V^2y}{50}$ where Vy is the vertical speed in feet per second.

Drag rope 50 pounds, 220 feet long, will stop force of descent of 0.7 bag (6 feet per second) without hitting 60 feet trees.

When sun goes behind a cloud start throwing ballast at rate of one-third cup per minute to stay in equilibrium. Usual total about 1 bag. Allow at least 2 bags for transition from daylight to dark (clear sky). Increase of weight in a rain may be as much as 5 bags.

3. During flight

Speed (miles per hour) $= \frac{22}{t}$ where t is the time in seconds for the balloon to pass over a given point. Or: speed $= \frac{H}{4t}$ where H is the height above the ground in feet and this the time for an object to go through an angle of 20° from vertical.

Sound travels 1100 feet per second (for check on altitude by echo).

Save at least $2\frac{1}{2}$ bags for landing from 10,000 feet or over (see special landing instructions).

List of equipment for 19000 cubic foot free balloon

I. Dead weight 425 pounds consisting of

Gas bag	234
Net	42
Suspension ring	10
Basket	127
Valve Valve top	9
Valve cord Rip cord	3
	425

to which should be added:

II. Instruments —— pounds, consisting of
- Ballast cup (to hold 3 pounds of sand)
- Barograph
- Statoscope
- Compass
- Speed indicator
- Stop watch
- Pencils
- Electric flashlight
- Knife
- And for very precise work, an asperating thermometer.

III. Emergency ballast:

Drag rope	$45\frac{1}{2}$
Gas bag packing cloth	8
Valve case	1
Basket cover	5
Basket rug	
Empty sand bags	20

IV. Ground Equipment:
- Ground cloth
- Eighty sand bags
- Inflation tube
- Inflation sleeve

to which should be added:

Holding rope (about 20ft. of any strong rope)
Supply of sand
Repair material
Soap for valve.

V. Equipment for special occasions:

Life preservers
Pontoons
Water anchor
Ground anchor
Long paper tape for soundings
Smoked glasses for use above clouds
Megaphone
Binoculars
Electric torch or lantern
Camera, maps, camp chairs, blankets, provisions, etc.

TABLE OF BALLAST WEIGHTS

1 pound = 1 cup.
35 cups = 1 bag, 30 pounds.
5 bags = 1 person, 150 pounds.

ANGLE	SINE	TANGENT
5	0.0872	0.0875
10	0.1736	0.1763
15	0.259	0.268
20	0.342	0.364
25	0.423	0.466
30	0.500	0.577
35	0.574	0.700
40	0.643	0.839
45	0.707	1.000

1.61 km. = 1 mile.
3.20 feet = 1 m.
2.20 pounds = 1 kgm.
1.8° F. = 1°C.

Table height for a 19,000 cubic foot balloon will rise for a given amount of ballast discharged.

$$Z = A \frac{f}{F_0 - \frac{f}{2}}$$

Z = height in feet.
A = height of a homogeneous atmosphere = 26,217 feet.
f = ballast in pounds thrown over.
F_0 = total ascensional force of balloon = 1330 pounds.

BALLAST DISCHARGED	HEIGHT IN FEET OF ZONE OF EQUILIBRIUM
10	201
20	402
30	598
60	1210
90	1817
120	2600
150	3333
180	4104
210	4916
240	5772
270	5583

INSTRUCTIONS FOR LANDING

Just previous to landing bring the balloon down as low as possible without touching the drag rope. Secure the instruments in their cases. Instruct the passengers as to how to handle themselves while landing. The drag rope side of the basket becomes the rear of the basket after the drag rope touches and the top of basket when landing is made. By holding to the ropes on the rear side and bending the knees and standing on toes the shock of a hard landing may be avoided. No one must leave the basket until told by the pilot. Let the passengers know when the rip cord is pulled as it gives them a second or more in which to drop what they are

doing and to prepare for a possible shock. So far as handling ballast, valving, etc., is concerned, the flight is over as soon as the rip cord is pulled. Avoid drag-roping if possible, but do not let the rope get more than 100 feet above the ground. Take into account the relative direction of the lower currents where difference can be noted. After the drag rope has touched, disregard statoscope and watch ground. When you want to make the final descent do not be afraid to valve strongly from this point. Remember that it takes ten seconds to let out the equivalent of one bag of ballast and ten seconds seems a long time when hanging on the valve. It takes about fifteen seconds' valving to overcome the weight of the drag rope. It is better to land with a good sharp bump than to drag. If there is a strong wind, drop the valve cord and pull the rip cord at least twenty feet in the air. The utmost care should be taken to keep this point in mind as the time when it is most needed is when you are most liable to forget it in the press of other circumstances. Under usual conditions select one passenger to pull the rip cord and another to be ready with dispensable baggage.

The landing usually collects a large crowd and it is frequently possible to let the drag rope drag on the ground until two or three men can get hold of it and pull the balloon over to a convenient landing place nearer the road. In making a landing you will find it of advantage to consider the possibilities of getting back home; so landing near a road or railroad station may save you twelve hours.

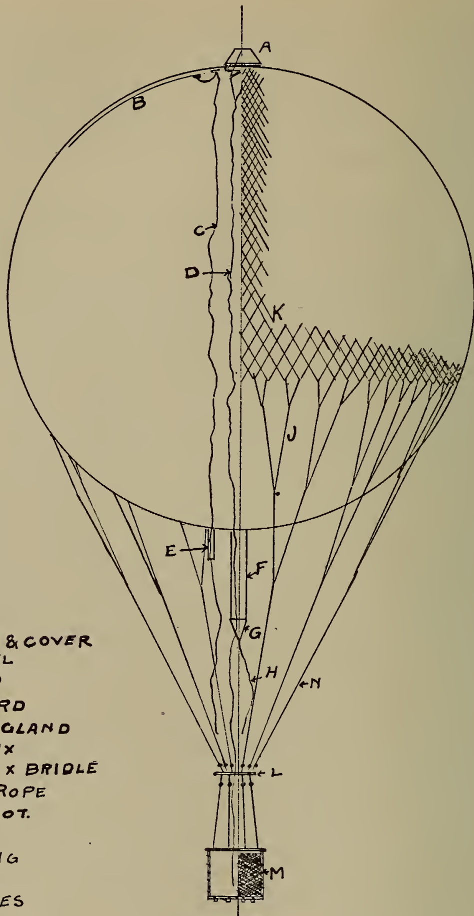
Landing with the use of an anchor is of great assistance where the possible landing place is small in area. Have the anchor ready with the line hanging out of the basket, clear for running. Calculate the length of the anchor line allowed; additional distance for possible dragging before getting a good hold, and let go anchor when this distance

from the desired landing place. As soon as anchor is let go, swing on to the valve cord and keep valve open until ready to rip. The anchor is very useful when making a stop landing, also when making a landing from over the bay onto the beach.

INSTRUCTIONS FOR NIGHT FLIGHT

Making a balloon flight at night appears to be a dangerous thing to undertake to the beginner, but in reality there is no added danger, providing the pilot keeps track of his position and does not have to land on account of weather conditions. On the contrary, the balloon sails along in a very stable atmosphere, and requires very little attention so far as ballast is concerned. The sun going down will cost two or more bags of ballast, and then one or more bags will be expended until the temperature of the balloon has adjusted itself, but after that a few cups now and then will be sufficient to keep the altitude. The altitude to maintain depends on the nature of the country. With fairly level country, it is best to keep an altitude between 1000 and 2000 feet. At this altitude one can hear the noises on the ground, such as chickens, dogs, trains and the wind in the trees, which will act as a check on the altitude, and can see the numerous lights, and on clear nights railroads, streams, roads, by means of which course and speed can be obtained and position located on the chart.

It is best not to get above the clouds at night, but if you do, do not remain above more than one or two hours, especially when near water, as one loses all knowledge of speed or course when out of sight of ground. All clouds look bad at night, but a rain cloud can usually be recognized and it is best to make a landing before the increased wind strikes you. Thin dew clouds may be seen below



A GAS VALVE & COVER
B RIP PANEL
C RIP CORD
D VALVE CORD
E RIP CORD GLAND
F APPENDIX
G APPENDIX BRIDLE
H BRIDLE ROPE
J CROW'S FOOT.
K NET
L LOAD RING
M BASKET
N FOOT ROPES

THE SPHERICAL FREE BALLOON

HALF OF BALLOON SHOWN IN SECTION.

Fig. 24

you during the night. These should not trouble you, as there are many pockets through which the ground is seen. In the early morning dew settles on the bag in sufficient quantity to drop down into the basket, and cost a bag or more ballast. It is wise to take along rain clothes even on a clear night on account of this dew. During the early part of the night the temperature between 1000 to 2000 feet is frequently warmer than that near the earth, but after midnight the temperature begins to fall and heavier clothing is needed.

If forced to land at night, drop rope over the tops of the trees until an open space is found. Even on the darkest nights the ground can be seen from the heights of the trees, and there is no danger if you do touch an occasional tree.

At sunrise the balloon will begin to ascend, due to heating of the gases and drying out of the balloon. Unless you wish to make a landing soon after sunrise, it is best to let the balloon ascend, as the altitude will not be increased more than 1000 to 2000 feet.

See figure 24 of inflated balloon for names of various parts, etc.

CHAPTER XLIII

Dilatable or Expanding Gore Balloons

Dilatable or expanding gore balloons have recently come into use in this country. They are at present used for aerographical research work and are similar in appearance to the late type kite balloons. They are much smaller, however, in that the Navy type under normal conditions upon the ground has 5000 cubic feet capacity with 0.35 inches of water pressure. Placed on each side of this type of balloon and running in a longitudinal direction in the lower half of same is one gore in a semi-collapsed condition. This condition is brought about by the means of $\frac{3}{16}$ inch square elastic cords being attached to the reinforced edges of the gores above and below the collapsed gores on each side. This balloon when sent aloft with aerological instruments, the gas begins to expand, but instead of the gas escaping through an automatic valve or an appendix it expands the gores previously mentioned, as the increased pressure stretches the elastic cords, thus increasing the capacity of the balloon from 5000 cubic feet capacity to 7400 cubic feet capacity under about $1\frac{1}{4}$ inches water pressure; this balloon will have a ceiling of 4000 to 5000 feet. If, for any reason, it is desired to lift a greater weight than the normal condition of inflation will lift, the balloon can be inflated to more than its normal diameter on the ground, provided the altitude to which it is allowed to ascend is correspondingly reduced so that there is no danger of producing an internal gas pressure of more than $1\frac{3}{4}$ inches of water when the balloon ascends, and the gas is heated by the sun.

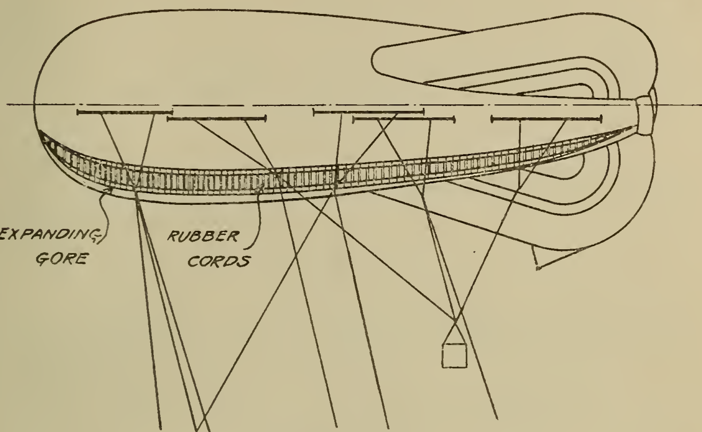

EXPANDING GORE
RUBBER CORDS

FIG. 25.

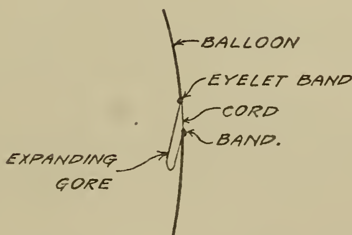

BALLOON
EYELET BAND
CORD
BAND.
EXPANDING GORE

FIG. 26.

It is to be noted that the rubber elastic cords are subject to rapid deterioration and should be taken up from time to time or renewed as necessary. See figures 25 and 26, showing location of expanding gores, elastic cords, etc.

CHAPTER XLIV

Formula Aerostatics

BOYLES LAW

The temperature remaining constant, the volume varies inversely as the pressure.

CHARLES LAW

The pressure of gas remaining constant, the volume varies directly as the temperature.

BOYLES AND CHARLES LAWS COMBINED

Boyles law gives the relations that volume varies inversely as the pressure while with Charles law the volume varies directly as the absolute temperature; combining these relations we have:

V varies as $\frac{T}{P}$ or $PV = RT$, which is the fundamental

gas formula, P being the pressure, R the numerical constant for the gas in question and V the volume of a given portion of gas at the absolute temperature T.

For example, a balloon has a capacity of 10,000 cubic feet at 70°F. and 30 inches of mercury pressure and it is required to determine its volume at 60°F. and 25 inches pressure. We have:

$$V = V_0 \frac{P_0 T}{P T_0} = 10{,}000 \frac{30 \times \ 460.6 + 60}{25 \times (460.6 + 70)} = 11{,}820 \text{ cubic feet.}$$

If the density of gas at 70°F. and 30 inches pressure is

0.005 pound per cubic foot and its density at 60°F. and 25 inches pressure is desired the formula would be as follows:

$$d = d_0 \frac{PT_0}{P_0T} = 0.005 \frac{(15 \times 460.6 + 70)}{(30 \times 460.6 + 60)} = 0.00423$$

If any two of the following four quantities are observed, the others can be computed—$P\ V\ T\ D$. If, for example, the pressure and temperature of dry air be observed at any point, its density can be computed from the formula, also its volume per pound weight and thence its volume for any weight. It is important, therefore, to be able to measure satisfactorily at least two of the four quantities in the studies of the atmosphere, the pressure and temperature are observed by instruments too well known for repetition here.

To determine the lift of gas by the law of Boyles and Charles, which is as follows: $P_0 = 30$ inches.

$$V = V_0 \frac{P_0T}{PT_0} \quad T = 460.6 + 70 = 530$$

Standard condition P_0 and T_0 are 30 inches barometric 70°F. under which one cubic foot of pure hydrogen lifts 0.07 pound.

Law of Dulong and Petit:

$$d = d_0 \frac{PT_0}{P_0T}$$

From the above laws there has been deduced an entirely different formula which by the use of constants which was derived from the law of averages and the above formula is considered and believed to be correct within 50 pounds in computing lift to an altitude of 10,000 feet.

Lift in pounds $= V\ 1.2366\ \frac{\mathrm{P}}{\mathrm{T}}$

Lift—in pounds.
V = volume in cubic feet.
P = Barometer in inches.
T = 460.6 T° in Fahrenheit.

$$\text{Lift} = V\ 0.07 - \frac{\text{H}}{1000}\ 0.00125$$

Lift = lift in pounds under standard conditions.
H = altitude in feet.
V = volume in cubic feet.

$$\text{Ceiling of airship} = 32.7\ \frac{\text{Ballonet capacity}}{\text{volume of airship, total.}}$$

Multiply ceiling by 1000 to have it in feet altitude.

CHAPTER XLV

Method of Preventing Tail Droop in Envelope of Airships

In order to prevent the tail droop in envelopes of airships a gripe is suspended from the gutter of the roof of the hangar by the means of two single blocks that allow it to pass under the envelope aft of the fins. Sand bags are hung on the lower ends of the lines coming from the blocks so that they take up the strain whether the ship is on the deck or rises a little off the deck.

A somewhat similar method has been used in which, instead of the gripe passing under the tail of the envelope, attachment was made directly to the horizontal surfaces. However, the method using the gripe seems to be simpler and more easily applicable.

As soon as the ship is brought into the shed or hangar and secured, the weight of the tail should be picked up on the gripe and should not be removed until the ship is prepared to leave the shed.

The above method preventing tail droop has been tried with noticeable success.

CHAPTER XLVI

Airship Mooring

There have been two systems of mooring airships in the open, and both systems have proven more or less satisfactory. In order to moor an airship a clearance of sufficient size should be selected before attempting to moor same in order that the ship can swing clear in any direction. The three wire plan after trials has proven to be most satisfactory for non-rigid type airships. This plan consists of utilizing the forward bridle with an additional length attached to the underside of the balloon in the rear of the bridle connection forming a triangle with sides of about 50 feet in length with weights, or sand bags, of about 125 pounds being suspended to the after handling guys. If the foregoing weight is found to be insufficient, the weight may be increased to 150, 160 or 175 pounds as may be found necessary in order to keep the ship steady.

The other method which has been tried abroad with more or less success consists of fitting an airship with a special rigid nose by which the ship may be attached to a mast for mooring out.

The attachment consists of a built up wooden spar 15 feet long which is rigged in the envelope with a steel fitting at the forward end, around which a sleeve at the nose of the envelope is tied off. The fitting terminates in a solid detachable end piece formed with an eye by means of which the ship is pinned to the mast. A wire passes through this end fitting and through the center of the spar to the after end where it is divided into four wires which are attached to a tubular ring 12 inches diameter. From this

ring 52 strings radiate forward in the form of a cone (whose base is 18 feet in diameter) to patches on the inside of the envelope.

From a flange on the eye piece at the foremost end of the spar six wires are led back to Eta patches These wires form a cone which is opposed to the cone formed by the strings. These two cones serve to attach the spar (and with it the eye at the foremost end) to the envelope, with a fair degree of rigidity. It is easily seen that the spar cannot move relatively to the envelope as a whole unless the annulus where the strings are attached is deformed.

The device is further intended to serve the purpose of the usual nose stiffener. To this end, that part of the nose over which the external pressure is greater than the normal internal pressure at full speed has been replaced by a new piece about 4 feet 6 inches in diameter of reversed curvature.

The wire which passes through the center of the spar is brought out through a clamp in the eyepiece and a free length of about 70 feet is left which is used to bring the ship up to the mast and is intended to be attached to the car during flight. By loosening the clamp the wire may be hauled through the spar to adjust the tension of the strings of the rear cone, the wire being then reclamped. This can be done while the ship is attached to the mast. A rotating casting is fitted to the head of the mast designed to receive the wire at the head of the spar.

The procedure when attaching the ship to the mast is as follows: A hemp rope is laid over the mast head in a forked guide and one end is then made fast to the wire from the ship's nose. The other end of the rope is then hauled through a block on the ground.

When the wire reaches the mast head the pull is eased and the wire is lifted into a groove in the casting and the ship hauled up until the eye enters the casting. The pin

is then inserted. A stern rope is used to check the approach to the mast and the ordinary handling guys are, of course, used.

This latter method has been used in mooring out non-rigid airships and while more or less satisfactory it is not considered as satisfactory for non-rigid type airships for mooring purposes as the three wire method mentioned in the foregoing. However, it may be used satisfactorily for the smaller non-rigid type of airships, whereby the nose of the airship can be sufficiently reinforced to take care of the nose fitting and the strain can be distributed over a greater area; then this method will be far more satisfactory than the triangle bridle suspension.

A cheaper, but tried, method of mooring rigid airships, more of an emergency measure, is the three wire system. This requires in addition to the landing ground fixed concrete anchorages with some simple gear for the three mooring cables.

The mooring mast previously referred to is constructed of steel and on the latticed principle. All of the details in connection with the best methods and principles of mooring airships are at the present period in a stage of evolution. Therefore, only a general description of the methods which have been tried is given.

The following is a general description of an airship mooring mast erected at Pulham, England:

The mast itself is a web-steel structure 115 feet in height with a revolving circular platform housed-in at the top and above the platform a mooring apparatus in cylindrical form swung on gimbals which permits the ship when moored to sway with the wind and swing to all points of the compass.

In addition to an elevator for passengers and freight purposes, the mast contains pipes for furnishing water ballast, gasoline, lubricating oil, and lifting gas for the airship.

It is said that the rigid airship, R-33, sister ship of the R-34, which crossed the Atlantic to the United States in 1919, has been moored to one of these masts. She has ridden out gales when the wind reached a velocity of 90 miles per hour, and she has been moored and released from the mast at wind speed as high as 50 miles per hour without damage or mishap.

The method of mooring with this type of mast is as follows:

When an airship approaches a mooring mast a cable, which runs from a winch from the ground up the mast and through the cylinder, is led down again to the ground and out to a point about 600 feet from the mast in the direction from which the airship is approaching. Two men stand by the end of the cable, one man at the winch, and three to five others in the top of the mast. They transmit signals and operate the cables and machinery.

The airship approaches the end of the cable lying on the ground at a height of about 500 feet, her mooring being let down in a loop. When the loop is over the end of the cable stretched out on the surface, the outboard end of the cable is dropped to the ground. It is then shackled up to the mooring mast cable and at a signal from the men on the ground, ballast is discharged from the airship until she is about 2 tons light, and trimmed down at the stern. She then rises to a height of about 1200 feet above the trim.

At a signal from the airship, "Haul down," the winch is started and the cable draws the airship down toward the head of the mast. When the airship is about 500 feet above the top of the mast two other cables about 600 feet long are let out, leading from the bow of the ship, and these cables are secured to two surging cables on the mast and the ends of the two cables are drawn up by lead lines

to the forward hatch of the ship. From then on, a strain is maintained on all three cables and the airship drawn down until a cone on her bow fits into a cone on the top of cylinder of the mooring mast. When the two cylinders are firmly "set home," locking springs lock the ship to the mooring mast.

An airship moored to a mast must always be kept trimmed down by the stern. And this is also true when landing or getting away, otherwise gusts of wind downward on the bow of the ship would throw her stern up and cause her to surge about and "whip" in the air.

To release an airship from a mooring mast, it is only necessary to let down a pendant from her nose throuh the revolving cylinder where a tension is put on it by a hand reel in the top of the mast, and the strain is held until the locking springs are free. In the meantime the after engine has been started to neutralize the force of the wind which tends to drive the airship astern. When all is ready, the remaining engines are started up, the locking springs are pulled back, and the ship rises free from the mast.

These masts do away with landing dangers in inclement weather. They also make it easier for passengers to enter the ship, for, after the passengers are landed in the revolving platform, they merely step through an "accordion" doorway similar to the connection between parlor cars on a passenger train, and walk down the passage into the ship's cabins.

As yet this type of mast has not been built in the United States.

CHAPTER XLVII

Lighter-Than-Air—Aircraft Don't's

a. Don't allow either engine to be run while inflating or deflating in a shed or hangar, or while filling gasoline tanks.

b. Don't run gasoline through chamois unless funnel is grounded to can and car.

c. Don't run the engine full power more than necessary, especially on the ground.

d. Don't exhaust all the fuel from the forward or largest tank as this is the only one that supplies the small engine (blower).

e. Don't forget the emergency tool kit (carried in airship).

f. Don't carry more total load in the car than that indicated under useful load. Put air in the ballonet instead.

g. Don't get the handles of the dampers on the air scoop on so that the dampers cannot be closed. Check this so that the handle will be up when the damper is closed.

h. Don't allow men with other than rubber soled shoes to walk on bag, and then only when absolutely necessary.

i. Don't allow sharp edges of fins to injure envelope.

j. Don't allow any kinks in cables, suspension or control.

k. Don't try to locate car by load rings. Check alignment by having it in line with front nose rope and tail rope. Measure from top of longeron, the front end of the car should be —— feet, and the rear end —— feet from the bag. (According to blueprint.)

l. Don't lead the control valve cords so that they will get foul of the propellers.

m. Don't have undue stress on cables. All suspension

cables should be proportionately tensioned. Use tension meter and apply tension as per assembly diagram.

n. Don't have control cables to elevators and rudder set up too tight. There should be no sag in them with 1 inch gas pressure in envelope.

o. Don't forget to examine the fire extinguisher and see that it is properly charged and in place.

p. Don't forget in balancing the ship with all loads in place that the ship should be evenly balanced (power off).

q. Don't let the pressure go above 1.5 inches as shown by the manometers, or below 0.7 when under power.

r. Don't run the engine when the bag has been allowed to buckle. Throttle or stop the engine altogether and rise slowly by use of ballast until pressure is restored.

s. Don't use the blower during flight unless the main engine is out of commission.

t. Don't discharge gas simultaneously with air unless sure that there is a surplus.

u. Don't wait for the safety valve to blow if you can conveniently help it.

v. Don't, under any condition, exceed 25 degrees angle either up or down as the suspension is not designed for more.

w. Don't try to put the ship in the hangar with a cross wind of 25 miles per hour without sufficient men. As many as 12 men can be placed on any one of the $\frac{3}{16}$ inch cables that pull essentially tangential to the gas bag.

x. Don't touch or come within six feet of a valve, either air or gas, while it is blowing, except in the following cases: (a) For adjustment of air valve, the air may be blown through for several minutes to be sure of flushing out accumulated hydrogen that has diffused through, after which the valve may be freely touched when necessary during the process of adjustment. (b) In the case of gas valves, if it is necessary to touch them while they are

blowing, contact with the body should be made before they have started to blow and continue until they have stopped.

y. Don't use anything but high test benzine, when washing balloon fabric or diluting cement.

z. Don't store a balloon away in a damp warm place. It should be stored in a dry cool dark place, as sunlight is injurious to rubber.

AA. Don't fail to use a gas mask when it becomes necessary to dope the fabric on the interior of airships, otherwise you may be overcome by the dope fumes.

CHAPTER XLVIII

Things to Remember About Airships

1. That valve and other adjustments change with time especially during the first few days, in a new balloon just rigged.

2. To inspect the balloon systematically, always with a view to preventing trouble in the air.

3. That emergency repairs may often be made in the air and a few simple tools should be carried for this purpose.

4. Not to use the gas bag as a rug, or as a means of concealing small objects. No pins, tacks, or bottles should be allowed in the hangar. Put a rope rail around the bag to prevent walking on it.

5. That hydrogen gas is highly inflammable, and dangerously explosive when mixed with air.

6. That one may easily without warning be overcome by breathing gas around valves, etc. When working on a tall ladder around the balloon, it is best to be tied on.

7. Always to leave the magneto switch off and the spark retarded when not running the engine.

8. To keep clear of the propeller when it is moving or when there is a man at the engine.

9. That it takes careful steering to hold the nose into the wind after the drag rope has been caught.

10. To have a surplus lift for landing.

11. Not to try to land like an aeroplane. Always use the drag rope on land or water.

12. That the tail swings opposite to the direction in which you turn. Always allow plenty of room.

13. To watch the manometers.

14. The propeller stream is what runs the ship. One square foot of flat surface or its equivalent behind the propeller cuts down the speed approximately one mile per hour.

15. Not to run more than 1200 revolutions unless necessary. This will cut in half the danger of engine trouble.

16. By sacrificing gas during flight you can do many tricks successfully that you pay for later at landing.

17. All valves should be rechecked after one days flying and then again within four or five days when the bag is new. The air valves are subject to other variations and should be checked frequently.

18. When adjusting gas valves be very careful about static. Touch hands to the bag (fabric) first before touching the valve or any other metal part connected to the bag.

19. To have three or more bags of sand ballast open and ready to dump at a moment's notice, but so that they will not be dumped until required.

20. To fly high if carrying a surplus load.

21. To throttle engine and close air damper simultaneously with the dropping of the drag rope. Be ready to throw out ballast again if the men fail to get the drag rope.

22. To keep the nose into the wind with rudder and assist with engine if necessary as the balloon is pulled slowly to the ground.

23. That when rear ballonet is full of air its pressure is 0.7 inch higher than the gas, and forward ballonet is 0.5 inch higher than the gas.

24. And that a down tilt of more than 15 degrees reduces the pressure in the nose below that indicated by the gas manometer.

25. Never to let the balloon stand needlessly with air in the ballonets. Air or gas must be put in, however, if the pressure gets below 0.4 inch. Maintain a gas pressure of about 0.5 inch as far as possible.

26. To analyze the gas once every 24 hours, as long as the purity is above 90 per cent. When the air content becomes greater than 15 per cent deflate and refill with pure gas.

27. That one $\frac{1}{8}$ inch hole in the fabric of a gas bag will let out more gas than escapes by diffusion through the entire fabric of the balloon.

28. To keep hangar doors open whenever possible, especially when inflating or valve testing.

29. To have one parachute for each man in the car before leaving the ground, properly secured in place and each man informed as to which he is to use. Harness to be worn at all times with parachutes ready to be hooked when leaving the ground.

30. Never pack a parachute when it is damp, moist or wet.

CHAPTER XLIX

Aircraft Engines

PRELIMINARY UNITS AND DEFINITIONS

Q. 1. What elementary units and terms connected with the generation of power must be known in order that the study of the operation, maintenance and repair of aeronautical engines may be understood?

A. (1) Force; (2) work; (3) energy; (4) power; (5) horse power (indicated horse power and brake horse power); (6) friction; (7) mechanical efficiency; (8) thermal efficiency; (9) compression; (10) combustion; (11) torque; (12) torque reaction; (13) inertia.

Q. 2. What is force?

A. Force is that which causes acceleration or retardation of a body.

Q. 3. Define work.

A. Work is the overcoming of resistance through space. Work is usually expressed in terms of foot-pounds. If a force of 10 pounds acts through a distance of 10 feet, it will do 100-foot pounds of work.

Q. 4. What is energy?

A. Energy is the ability to do work.

Q. 5. What is power?

A. Power is the rate of doing work and is the amount of work accomplished in a given time.

Q. 6. Define horse-power.

A. Horse power is the practical unit of power, one horse-power being equal to that amount of work which is done when a weight of 33,000 pounds is raised one foot in one minute of time. The abbreviation "H. P." is used to denote horse-power.

Q. 7. Define indicated horse-power.

A. The indicated horse-power of an engine is the power developed in the cylinders by the pressure and expansion of the gas. It is determined by the formula

$$\frac{\text{P.L.A.N.}}{33{,}000} = \text{I.H.P.}$$

P. represents M.E.P. pounds (Mean Effective Pressure).

L. represents the stroke in feet.

A. represents the area of the piston head in square inches.

N. represents the number of power strokes per minute.

The pressures in the cylinder are determined by means of an instrument known as an "Indicator" which records the varying pressures during the cycle.

Q. 8. What is brake horse-power (B.H.P.)?

A. Brake horse-power is the actual horse-power available after all losses due to friction, heat, etc., have been overcome. Brake horse-power is usually determined by use of dynamometer or Prony brake, the dynamometer being the most suitable means. The dynamometer consists of a dynamo which is connected to and driven by the engine being tested. The amount of electricity generated by the dynamo is measured in terms of Watts, 746 Watts being

equivalent to one horse-power, and in this manner the number of Watts generated determine the horse-power of the engine.

Q. 9. What is frictional horse-power?

A. Frictional horse-power is the power consumed in overcoming the friction of the moving parts and is approximately 5 per cent of the power developed.

Q. 10. Define mechanical efficiency.

A. Mechanical efficiency is the percent of efficiency obtained from an engine in the mechanical sense. The proportion found by dividing the B.H.P. by the I.H.P., expressed as percentage, would be the mechanical efficiency.

Q. 11. What is meant by the term "thermal efficiency?"

A. Thermal efficiency is the ratio of the energy given out at the crankshaft and the energy supplied in the form of fuel. Each pound of fuel supplied contains a certain amount of inherent energy, this energy being expressed as British Thermal Units, each B.T.U. containing the equivalent of 778 foot-pounds work. By comparing the weight of the fuel consumed over a given time to the amount of energy received from the engine during the same time, and subtracting the frictional losses, is found the thermal efficiency of the engine, which is expressed in terms of percentage.

Q. 12. What is meant by the term "compression?"

A. Compression is the act performed by the piston of causing the gas in the cylinder to occupy a smaller space. In an aeronautical engine, compression is performed by the piston on what is known as the *compression stroke.* The charge having been drawn into the cylinder, the piston is

at the bottom center; all valves are then closed. The piston during the up-stroke (compression stroke), compresses the gas, confining it at the end of the compression stroke in the combustion chamber at high pressure. By compressing the gas its temperature is raised nearer to its ignition point and it is more easily ignited and gives off more explosive power than if at atmospheric pressure.

Q. 13. What is combustion?

A. Combustion is the burning of the compressed charge in the combustion chamber and is usually referred to as as explosion.

Q. 14. What is torque?

A. Torque is the twisting motion applied to the crankshaft by the reciprocating motion of the pistons which is transmitted to the crankshaft by the connecting rod and crank.

Q. 15. What is torque re-action?

A. Torque re-action is the re-action applied to the stationary parts of the engine by the torque and is of course in an opposite direction to the direction of rotation of the crank-shaft. Torque re-action is the tendency of the stationary parts of the engine, such as crankcase, cylinders, etc., to rotate in an opposite direction to that of the crankshaft.

Q. 16. What is inertia?

A. Inertia is the tendency of a body at rest to remain at rest, or of a body in motion to continue in motion, until acted upon by some outside force.

AIRCRAFT ENGINES

Q. 1. What is an internal combustion engine?

A. An internal combustion engine is a machine which converts the heat energy in a volatile fuel (gasoline) into mechanical energy.

Q. 2. Give a brief description of an internal combustion engine?

A. An internal combustion engine consists of one or more cylinders into which a charge of gasoline vapor and air is drawn, compressed into a combustion chamber and exploded. The force of the explosion and rapid expansion of the charge forces a piston downward within this cylinder. This reciprocating motion is converted to a rotary motion through the medium of a connecting rod and crankshaft. A carburetor is used for mixing this gasoline vapor and air in the proper proportions, and is connected to the cylinder with a pipe known as the intake manifold. Some electrical device must be used to ignite or light the charge at the right time, and this electrical device may be either a *magneto* or a battery generator combination. The admission of this charge into the cylinder must occur at the proper time, so it is controlled by an intake valve. After it is burned it must be expelled to the atmosphere at the right moment, and this is controlled by an exhaust valve. A crank case encloses the crankshaft, and also serves as a receptacle for the oil, as well as holding the bearings.

Q. 3. Into what two general classes are internal combustion engines divided?

A. Internal combustion engines are divided into two separate classes: (1) Two stroke cycle, (2) four stroke cycle.

Q. 4. Explain the operation of a two stroke cycle engine?

A. In the two stroke cycle engine the mixture of gasoline and air is drawn into the cylinders exploded and forced out in one complete revolution, giving us a power stroke every revolution.

Q. 5. Explain the operation of a four stroke cycle engine?

A. In a four stroke cycle engine we have a power stroke every 4 cycles (or movements of the piston from lower dead center toward upper dead center), which gives a power stroke every two revolutions, for two movements or cycles occur every one revolution (once from upper dead center downward and once from lower dead center upward), In defining each cycle of operation in its turn we start with:

1. *Suction.* During this cycle or movement of the piston downward, a vacuum draws into the cylinder a mixture of gasoline and air in proper proportions, which later on is to be used to give us our power. During this time the intake or inlet valve is held open.

2. *Compression.* During this cycle or movement of the piston upward, the intake or inlet valve closes, so this charge of gasoline and air is compressed within the combustion chamber. While doing this we cause this charge to become so hot that it is almost to the point of exploding. By compressing the charge we also increase its explosive energy.

3. *Combustion.* During this cycle of operation we ignite the compressed charge, exploding it, thereby forcing the piston downward. This cycle is the one that gives us our power, and it is stored in a fly wheel, or in the case of an aircraft engine, in the propeller. This portion of the energy so stored enables the engine to run over the three cycles

that do not give back power, namely, suction, compression and exhaust.

4. Exhaust. When the piston reaches bottom dead center the exhaust valve opens, and as the piston starts moving toward upper dead center it creates a pressure within the cylinder which forces the burned gases out into the atmosphere, so we are now ready to start over again on number one or the suction stroke.

Q. 6. What is an aircraft engine?

A. An aircraft engine is an internal combustion engine, more refined in design and construction than either the stationary, marine or automobile type engine, and which is especially adapted for use in all types of aircraft. It is designed with the view of obtaining the maximum power from a minimum amount of weight and a low fuel consumption.

Q. 7. Into what classes would you divide aircraft engines?

A. There are two distinctly different types of aircraft engines.

1. The fixed or reciprocating type.
2. The rotary or revolving type.

The fixed type in turn is divided into several classes.

1. Cylinders all in line, upright, as in the case of the four and six cylinder engine.
2. Cylinders opposed and horizontal, as in the case of a very few two, four, six, eight and twelve cylinder engines.
3. Cylinders set V shape at an angle of 45 to 60 or 90 degrees, as in the case of most eight and twelve cylinder engines. As a general rule all eight cylinder engines are set with the cylinder banks 90 degrees apart. This is done to make the power impulses even, or in other words, to occur every 90 degrees. In the case of twelve cylinder engines, the cylinder banks should be spaced at an angle of 60 degrees to

insure an equal flow of power, but some engineers have spaced their cylinders 45 degrees in order to decrease the amount of head resistance, and at the same time eliminate friction (or at least reduce it to a minimum). When the cylinder banks of a twelve cylinder engine are set at an angle of 45 degrees, the power impulses do not occur evenly, but 45 degrees and 75 degrees apart, however it is assumed that the gain by reducing heat resistance and friction more than compensates for the unequal application of the power impulses.

4. Cylinders spaced equally in a circle as in the radial type of engine.

5. In the rotary or revolving type of aircraft engine, the cylinders are spaced equally apart in a circle, and the crankshaft is held stationary, allowing the cylinders and crankcase to revolve, just opposite to the fixed type of aircraft engine where the cylinders and crankcase are stationary and the crankshaft revolving. Both the fixed and rotary types have advantages and disadvantages which we shall discuss later.

Q. 8. What advantages has the fixed or reciprocating type of aircraft engine over the rotary or revolving type?

A. Although as a general rule all fixed types of aircraft engines are somewhat heavier than the rotary type, for they generally weigh from 3 to 4 pounds per B.H.P. against the 2 to 3 pounds per B.H.P. for the rotary type, the per cent of thermal efficiency is very much higher in the fixed type of aircraft engine. Therefore the fuel consumption is correspondingly lower. With this in mind we should then select a rotary motor for high speed aircraft that are to fly only short trips, for that would reduce the amount and also the weight of the gasoline that would have to be carried. The fixed type should be used for low speed long trip machines, as the low

fuel consumption also reduces the weight of the fuel, as we would not have to carry as large an amount as necessary for the rotary type flying an equal distance. Then, too, the fixed type is more reliable than the rotary for several reasons. As a rule they are water cooled, which is about 20 per cent more efficient than air cooling. We can secure a greater number of flying hours between overhauls with the fixed type, for in the rotary type the centrifugal force throws the oil out into the hot combustion chamber where it carbonizes, and this carbon deposit must be removed very often in order to secure satisfactory operation.

Q. 9. Explain briefly the operation of the rotary engine?

A. Of this type the "Gnome" is the best known, and in describing the operation of the rotary engine, the 100 H.P. "Gnome Monosoupape" engine will be used.

In describing the Gnome, the word Monosoupape means 1 valve or single valve. In the very early type of Gnome, there were two valves, one in the piston head and one in the cylinder head. However, the valve in the piston head was very hard to adjust, and sometimes if it didn't seat exactly right, fire and even explosions would occur. The modern Gnome engine has a single valve to allow the exhaust gases to leave, and by passes the mixture from the crankcase in a way very similar to that used in two cycle engines. The hollow crankshaft serves the purpose of a gasoline and oil pipe. Gasoline is forced through this shaft under a pressure of 5 pounds per square inch, and therefore we have a very rich mixture in the crankcase. The exhaust valve remains open long after the burned gases are expelled from the cylinder, which allows a charge of fresh air to be drawn in. By drawing in this fresh air charge, we dilute this very rich mixture to the proper proportion, and at the same time cool the cylinder to some extent. It must be remembered that

castor oil must be used in all rotary engines, for a mineral oil would be destroyed by the action of the gasoline in the crankcase. It is not necessary to go further into details on rotary engines, for the fixed or reciprocating type is more commonly used, and from all indications will replace the rotary altogether.

Q. 10. What special makes of aircraft engines are used by the navy, and how are they classified?

A. The navy uses the Hispano-Suiza type "A" (150 H.P.) engine in the N-9 seaplane for elementary training, the Navy Liberty engine for the heavy flying boats, and the Union Aircraft engine for lighter than air work on airships. All these engines are of the fixed or reciprocating type of four stroke cycles. As all these engines operate on exactly the same principle, a detail study of the fixed or reciprocating type of engine will be made.

Q. 11. How would you determine whether or not a certain make of engine is suitable for aircraft work?

A. Three items must be considered to determine whether or not an engine is suitable for aircraft work. They are:

1. Unit weight per horse power.
2. Reliability, or its ability to run for a predetermined length of time.
3. Adaptability, meaning features and attachments of the engine which affect reliability.

Q. 12. How would you analyze the weight factor?

A. Weight must include all attached or detached accessories, such as radiator, fuel and oil tanks, water piping, fuel piping, instruments and connections. The supply weight, which is fuel, oil and water carried in flight, must be included, with reference to time of contemplated flight. When we

speak of the weight of an engine, we always refer to the power delivered; for instance, we say an engine always weighs so many pounds per brake horsepower. If the engine is any way near right the water will not be consumed to an appreciable extent, but oil and gasoline are consumed so fast that it makes a big difference as to how much is to be carried. It is understood that the enlisted personnel concerned with the operation of aircraft engines will never be called upon to decide which engine is best and how fuel consumption affects the weight of the load to be carried. But proper adjustment of the carburetor will make a vast difference in fuel consumption so it always should be done very accurately.

Q. 13. How would you determine whether or not an engine is reliable, and how could you aid in obtaining reliability?

A. In view of the fact that there is never absolute reliability in aircraft engines, we are forced to a comparison. Some engines are more reliable than others, and then, too, some mechanics are able to secure more flying time than others. Reliability is best measured by how many hours it will take before a drop in power and speed is noticed, or how many hours pass before a complete stoppage occurs. The Navy Department desires an engine to fly for seventy-five hours before it is overhauled, and this is easily done, providing the man on the beach directly concerned with the operation does his work well. Therefore, remember that no matter how carefully an engine is overhauled in the shop, it will not fly the required time unless the mechanician in charge handles it as any very delicate piece of machinery should be, and that is with great care. The mechanician should take great pride in having his engine turn up to a little above its rated speed; he should also notice every adjustment and see that "she" is running right up to "snuff."

Q. 14. What are the general causes of loss of power, breakage and stoppage?

A. The first and most important cause is power process derangements, and are those which include all operations concerned with power and fuel and not metal. These are not easily found, and are more continually present. The second is metal derangements, which always announce themselves soon, as a piston slap, loose bearings or gears and broken parts.

Q. 15. Give a complete definition of power processes?

A. The three power processes are:

1. The making of a suitable mixture and its introduction into the cylinder.

2. Involving the proper cylinder treatment of the working charge.

3. Adequate internal temperature control of the combustion chamber.

Even if all metal parts are correct, the engine will not run successfully unless the power processes are not concerned with the power given and the fuel consumption.

Q. 16. Analyze carefully the first power process mixture making; what should constitute a good mixture, and what harmful effects are caused by an improper mixture?

A. A mixture is said to be correct when it is correct in quality and quantity, or in other words, when the cylinder receives the maximum amount of the best kind of a mixture.

Judging quality. There is a natural tendency for gas and air to laminate instead of mixing. We mean by that, that the gas and air tend to form one against the other in layers instead of mixing thoroughly. Therefore, when we force the correct proportions of gas and air into a complete mixture, it is said to be of proper quality.

Proportion. The proportion that is correct is that which leaves no gas unburned or air unused; the exhaust should show no unburned gas or free oxygen. The correct proportion is 15 or 16 pounds air to 1 pound of gas, and if this is not reached air mixture is over rich or over lean. If our mixture is only slightly rich, we will gain a little more power when running fast, for combustion occurs faster, but this is not an advantage for when this excess of fuel comes into contact with the hot flame during combustion, it separates into hydrogen and carbon. When this carbon in turn comes into contact with the colder surface of the piston, it sticks there building up a deposit of carbon. Later on this carbon becomes incandescent or red hot and ignites the mixture before the proper time causing preignition, which in turn causes the engine to *knock.* It must be remembered that if we have an excess of 10 per cent gas, or a rich mixture, it is the same as wasting 10 per cent from the tank, and if there is a great excess of gas, there will not only be a great waste, but combustion will occur slower, causing a loss in power, and a gain of carbon. If our mixture is only slightly lean, the speed of combustion will be impaired, causing a loss of speed, power, and efficiency. If there is still a greater excess of air, we will backfire into the carburetor, which is extremely dangerous in aircraft work. It must be also remembered that carbon is an excellent non-conductor of heat, and this is a serious matter in aircraft engines, for they run hot at all times. The manifold should be smooth so as to offer the least resistance to the flow of gas. Any mixture of gases will weigh most when their pressure is highest and their temperature lowest; therefore, the charge must be kept as cool as possible and its pressure as high as possible, until the inlet valve closes.

Q. 17. Analyze carefully the second power process, involving the proper cylinder treatment of the working charge: ignition and combustion?

A. Before studying ignition and combustion, it must be noted that unless our cylinder is perfectly air tight, the compression cannot be very high. Therefore, valves must be ground very carefully in order that they will seat properly, and the valves and seats both must be examined for distortions or warpage, as it is impossible to secure a good fit unless the material fits squarely. The cylinder also should be tested for leaks. A good way is to fill it with illuminating gas and then run a light taper around the outside. When a flash is noted there will be a leak. Leaks can occur past the piston, so great care should be exercised in fitting the rings on the piston and the piston in the cylinder.

Combustion. Combustion should start, so that it will be completed when the piston passes over upper dead center. Instantaneous combustion is impossible; therefore, it must last over a certain length of time, and a certain number of degrees of crank travel, so for example, we will say combustion starts very soon after the piston passes upper dead center and lasts through a travel of from 10 to 20 degrees. The quicker the mixture burns the better, so we see that the ignition factor is of great importance.

Ignition. Ignition is means whereby the charge is ignited or lit by an electric arc within the combustion chamber. Great care must be exercised in adjusting ignition equipment, for in order that combustion will be caused to occur at the proper time, ignition must be timed correctly.

Q. 18. What are the essential elements of any electrical ignition system?

A. They are:

1. A simple and practical method of current production.

2. A suitable timing apparatus which should cause the spark to occur at the right time during the cycles of operation.

3. Suitable wiring to convey the current produced from either the generator or magneto to the spark plug within the combustion chamber.

4. A spark plug built to withstand the intense heat generated in the chamber.

Q. 19. Which of the two (single or double) ignition systems is best and why?

A. In aircraft work the double system is best for two reasons:

1. It increases speed and power.

2. Both systems seldom become inoperative at the same time, therefore, we are always sure of having at least one unit functioning properly.

Q. 20. Explain in detail the speed and power increase derived by the use of two spark plugs?

A. In our study of combustion, we have seen that the quicker our mixture burns, the faster our engine will run; then, too, power increases to a certain extent as speed increases. The compressed charge in the combustion chamber does not ignite all at once, but burns in spherical form radiating outward. In other words, the amount of gas nearest the spark plug will ignite first and spread outward somewhat similar to the action of water in a pool if one were to throw a stone in the center of it. First one would see a circle form where the stone hit the water, this circle in turn inducing other larger circles to form until the entire surface is agitated. Under ordinary conditions, that is to say in automobile or marine types of engines, single ignition will cause combustion to occur fast enough. In aircraft engines however we arrange a spark plug at either side of the com-

bustion chamber and ignite the charge in two different places causing combustion to occur almost twice as quick. It is well to remember that unless the two plugs fire at exactly the same time, one plug is useless; therefore, great care should be exercised in synchronizing the ignition units; or in other words, great care should be used in adjusting these units in order that they may fire together.

Q. 21. What methods of electrical current production are used in aircraft engines; which is best and why?

A. The magneto and battery generator systems are both used, and engineers disagree as to which is best. The magneto is more compact, as it generates high tension current within itself; however, with the exception of the "Dixie," they do not generate a heavy voltage at low speeds, and most generally a too heavy voltage at high speeds. As a general rule, it is easier to maintain a magneto in working condition, than it is a battery generator. Both of these systems will be studied in detail later on.

Q. 22. Analyze carefully the third power process involving internal temperature control?

A. Assuming that we have an excellent charge, and good working conditions, our motor would stop providing that the internal temperature, or the heat within the cylinder, was not controlled; therefore, adequate internal temperature control is absolutely necessary to insure the proper operation of an aircraft engine. An explosion that will generate the power derived from aircraft engines generates a great amount of heat, and this heat must be carried by the heat conducting parts to the water circulating through the jacket and radiator. The design and construction of the piston is an important matter, for it controls the heat in the cylinder to some

extent. An aluminum piston tapering from the center of the head outward and from the top downward should take the heat to the cylinder walls and thence to the circulating water, for aluminum is a very good conductor of heat. However, aluminum expands more than steel, or cast iron so greater clearance must be allowed. It must be remembered that no matter how carefully a piston is designed and constructed, it will not function properly as a heat conductor unless the mechanician uses the greatest care fitting it into the cylinder. The oil used in lubricating the cylinder walls is also used as a thermal bridge or heat path; therefore, the mechanic should at all times check his lubrication system in order that this thermal bridge may be maintained.

Q. 23. What two common adjustments are most important as to their effects on power processes?

A. The closing of the inlet or intake valve must be most accurately timed in order to insure the pressure resulting from high velocity to take place within the cylinder instead of in the manifold; this is more essential on aviation engines, in fact it is the most important adjustment on the engine.

The opening of the exhaust valve is next in importance. If this valve opens too soon we will lose power; if it opens too late we will not be allowed to empty our cylinder of all the burned gases.

Q. 24. Why is aircraft engine construction important, and how does it effect operation?

A. Unit weight per horsepower and reliability are dependent upon the proper construction or the arranging or forming of all parts, bearing in mind the function of the part and its relation to other parts. A general knowledge of construction, on the part of the mechanic, will insure more successful operation. The metal used in aircraft engine construction

is called upon to resist certain stresses, which may be divided as follows: tension, torsion, flexes, long column compression and short column compression. The ability of the metal to resist this stress is measured by its tensile strength, with exception of short column compression. For short column compression stresses castings will suffice. Heat treated alloyed steels are best in tensile strength, and therefore are good material for use in light weight parts subject to heavy stresses; cast iron and aluminum castings are good for low stresses in short column compression. Cylinders and pistons, owing to the stresses received, must be made accordingly. The cylinders have a tension applied to the extent of 10,000 pounds, and therefore should be made of steel; the piston receives only a short column compression stress, and therefore can be cast of aluminum. The frame or crankcase member is subjected to a bending and rotating stress; it should be made of aluminum and re-inforced with steel at the particularly stressed points. The bottom half of the case is unimportant. The crankshaft must be made of steel, therefore, its bearings must be either of bronze or babbitt, so that the shaft itself will be protected from wear. If bronze is used, the bearings must be carefully watched, and if babbitt is used, it must be fitted in a removable cap, that in turn is accurately fitted. This babbitt should be made in bushing form to do away with pouring. All moving parts, such as the piston, wrist pin, connecting rod, crankshaft, and camshaft, must be lubricated, and the metals that are in contact must be correctly related to one another. Steel cylinders have been found to be practical when soft pistons and rings are used. It must be remembered that different metals expand differently when heated to the same temperature; therefore, when two parts are in contact with one another they should be made of different metals, so that they will not expand equally and bind. Special care must be

exercised when fitting up an engine, so that the proper clearance will be allowed between the moving parts. It is always best to leave the clearance recommended by the manufacturer unless these are found by actual test to be incorrect.

Q. 25. Why is lubrication necessary in aircraft engines?

A. In any mechanism we have friction, which is a resisting force that tends to retard motion and bring all moving parts to a state of rest. We have noticed that about 5 per cent of the power the engine should develop is lost through friction, and you can always tell that it is present by the heat which exists at bearings. Friction may be divided into two classes, rolling and sliding. In order to secure durability and successful operation, as well as a high percentage of mechanical efficiency in aircraft power plants, it is absolutely necessary to reduce friction to a minimum. Although to all appearances, a surface which has been machined and polished, seems to be perfectly smooth, we would find it very rough if we should observe it through a microscope. When two surfaces are in contact with one another these minute projections have a tendency to cling to each other, unless an elastic oily substance is used to keep them apart. This oil spreads over all of the surface smoothing out the inequalities that produce heat and tend to retard motion. Rougher surfaces have more friction than smoother ones, and soft bodies will produce more friction than hard ones.

Q. 26. What kind of oils are best, and why?

A. Oil derived from a petroleum base, able to pass a good cold test, having a high flash point, and showing a good viscosity is best for aircraft use. We have already learned that oil as well as acting as a lubricant, must serve as a thermal bridge or heat path. Therefore, it is necessary to

have an oil with a high flash point. We mean by this, that our oil can be heated to a very high temperature before it flashes and burns. Oil used in Aircraft engines must also be able to hold its body under high temperature, therefore, it must be viscous. Aircraft engines are operated under all conditions of temperature, therefore, it is necessary to have an oil that will flow freely in cold weather as well as in hot weather. Requirements may be briefly summarized as follows:

1. It must have sufficient body to prevent the parts to which it is applied from seizing, but it must not be too viscous, in order to minimize the internal or fluid friction which exists between the particles of the lubricant itself.

2. The lubricant must not gum (as in the case of asphaltum base oils) and it must not injure the parts to which it is applied by chemical action or injurious deposits. It should not evaporate rapidly.

3. It should be selected, after a careful test, for the work for which it is intended, and must be a good conductor of heat.

Q. 27. How many types of lubrication systems are used; which is best, and why?

A. There are a number of different systems in use; the splash, the force splash system, and the full force feed. The splash system was commonly used in automobile practise, but owing to the fact that in the last few years the speed of automobile engines has been increased, the system is no longer practicable. This system required an amount of oil to be carried in the case that would allow the connecting rod to dip into it. The rod would oil itself this way, and at the same time, due to its rotary motion, throw oil on the cylinder walls and on the wrist pin. There is no way of regulating this system in a satisfactory manner; therefore, it is con-

demned for aircraft practise. The full force feed system with a dry sump is used quite extensively, and is considered best for aircraft engines, for oil is supplied at all angles, and under a constant pressure. The force splash operates in the same manner as the full force feed, with the exception that in the force splash system the cylinder walls and pistons are oiled by the splash from the connecting rods. The Liberty engine uses this system, therefore, shall be explained thoroughly later on.

Q. 28. Why must an aircraft engine be cooled?

A. It must be understood that the rapid combustion and continued series of explosions would soon cause the metal parts of an engine to become red hot, providing some means of taking some of this heat away were not supplied. The high temperature of these parts would burn away the oil and these parts would expand and seize, thereby wrecking the engine. Still another factor enters into engine cooling and that is, if the engine is allowed to run at too low a temperature, we lose a great amount of efficiency. Therefore, we can say the object of cooling is to keep the heat below the danger point, but at the same time have it high enough to secure the maximum amount of power to be received from the gasoline supplied.

Q. 29. How many cooling systems are used; which is best, and why?

A. There are two cooling systems used; air cooling and water cooling. Water cooling in turn is divided into two methods—the thermo syphon system, which operates under the theory that hot water rises and cold water falls, this causing circulation, and the force or pump system. Air cooling is considered inefficient and is never used on fixed types of aircraft engines. The thermo syphon system of water cooling is not positive enough for aircraft engines, therefore, the pump is used to circulate cooling water for

aircraft engines, and this system is best, as the water is circulated at a high velocity. All water cooled systems must have a radiator (or in other words, a combined storage and cooling tank), to cool the water after it has passed through the jackets. This radiator consists of two tanks mounted one above the other, and connected together by a series of pipes which may be round and provided with a number of thin fans to radiate the heat, or which may be flat in order to allow the water to pass through in thin sheets, in order that it will cool more easily. Radiators so designed are known as tubular radiators, and although they give very little trouble due to leakage, they are a trifle too heavy for aircraft use. A radiator which is composed of a large number of bent tubes, which expose a large area of the surface to the cooling influences of the draught of air caused by the forward motion of the machine, is known as a honeycomb or cellular radiator. While this type gives a lot of trouble from small leaks and is hard to repair, it is more efficient as a cooling medium, and fairly light in weight. The water is always taken from the bottom of the radiator, forced through a pump, and thence distributed equally to all cylinders. After passing through the jackets it is returned to the upper tank in the radiator, where it is broken into thin streams and allowed to filter to the bottom. By the time it arrives at the lower tank, it is sufficiently cool to be used again. The centrifugal type of circulating water pump is most commonly used, as it maintains a definite rate of circulation. It consists of an impellor of rotary form, which draws the water at a central point and forces it toward the outside. There are a number of items to be watched in connection with the cooling system of an aircraft engine. Our water service must be kept clear at all times. Only soft water should be used in the radiator. The temperature should never exceed 190 degrees, or should never be allowed to fall below 160 degrees.

CHAPTER L

Ignition Devices

Q. 1. What fundamental units of electricity must be understood in conjunction with the study of ignition devices?

A. These units are the volt, the ampere, the ohm, and the joule.

Q. 2. What is the volt?

A. The volt is the unit of pressure of electro motive force, necessary to force an ampere of current through a resistance of one ohm. It is expressed by the symbol (E).

Q. 3. What is an ampere?

A. The ampere is the amount of current that will flow through a resistance of one ohm, under the pressure of one volt. It is measured by an instrument called an ammeter, and is expressed by the symbol (I).

Q. 4. What is the ohm?

A. The ohm is the resistance through which the electro motive force of one volt will force a current of one ampere. It is expressed by the symbol (R). The ohm is also the resistance of 1000 feet of (B. & S.) copper wire.

Q. 5. What is the joule?

A. The joule is the unit of electrical work, and is the amount of work performed by a current of one ampere flowing for one second under a pressure of one volt.

Q. 6. What is the electric power law?

A. One watt is the power delivered when an electro motive force of one volt, forces a current of one ampere through the circuit, and is expressed by the symbol (W) or IxE = W. 746 watts are equal to 1 H.P. or 33,000 foot pounds in 1 minute.

Q. 7. What is the difference between insulators and conductors?

A. Any material that obstructs the flow of current is called an insulator or insulating material. Any body that offers only a slight resistance to the flow of current is called a conductor. No conducting body possesses perfect conductivity but offers some resistance to the flow of current. Therefore, conductors can be divided into three classes: good conductors, fair conductors, and poor conductors.

Q. 8. Name a few conductors, and insulators?

A. Some good conductors are silver, copper, aluminum, zinc, and brass. Some fair conductors are, charcoal and coke, carbon plumbago, acid solutions, and sea water. Some poor conductors are water, the human body, flame, linen, dry woods, and marble. Insulators are, slate, oils, porcelain, dry leather and paper, wool, rubber, shellac, sealing wax, and silk.

Q. 9. What is magnetism?

A. Magnetism is a property possessed by certain substances (lodestone, or leading stone, magnetic oxide of iron and others) and is manifested by its ability to attract and repel other materials susceptible to its effects. Magnetism may be produced in two ways. First, if a piece of steel is rubbed against another magnet, it will become magnetized and this is called magnetizing by contact. If this piece of steel is hard, it will retain this magnetism and thus become

a permanent magnet. Secondly, if a piece of steel is brought within the fields of a powerful magnet, it will also become magnetized, this being called magnetizing by magnetic induction. Also if a powerful electric current flows through an insulating conductor wound around a piece of soft iron or steel, it will be magnetized, this being magnetizing by electric magnet induction. Usually an electro magnet is made up of soft material; therefore, it would lose its magnetism as soon as the current is turned off.

Q. 10. Give a brief description of a magnet?

A. Magnet is a piece of steel, or other magnetized substance which possesses the properties of attracting other pieces of steel or iron, or other magnetizable bodies to it, and of pointing when freely suspended in a horizontal position toward the North Pole of the earth.

Q. 11. What is meant by the term "pole," when used in connection with magnets?

A. The ends of the magnet are termed its poles. The end which points toward the north geographical pole is the North Pole, and the other the South Pole.

Q. 12. What two rules govern the generation of electric current?

A. They are:

1. If a conductor, or a number of conductors, are placed in a magnetic field and caused to revolve or rotate so as to cut the magnetic lines of force, a voltage will be generated. This is dependent upon the speed at which the lines of force are cut, and upon the number of lines of force cut, or the strength of the field.

2. If a conductor, or number of conductors, are held stationary in a magnetic field and the field strength varied, a voltage will also be developed. This is dependent upon

the speed at which the field strength is changed and the amount of change taking place.

Q. 13. Define briefly an electric generator or dynamo?

A. It is a machine for converting mechanical energy into electric energy by means of electromagnetic induction. It does not create electricity, but produces or generates an induced electromotive force, which causes a current to flow through a properly insulated system of electrical conductors external to it.

Q. 14. Give a clear description of a generator or dynamo?

A. It consists of two essential parts. First, a magnetic field produced by electro-magnets and a number of loops or coils of wire wound upon an iron core, forming an armature, and so arranged that the number of magnetic lines of force of the field threading through the coils will be constantly varied, thereby producing a continuous electromotive force.

Q. 15. How are generator armatures wound?

A. Generator armatures may be either lap wound or wave wound. Most generators are lap wound. When we say that a generator is lap wound, we mean that the commutator has an even number of bars, and the winding progresses from one bar to the adjacent, and so on until all bars are included. In wave wound generators, the commutator has an uneven number of bars, and the winding starts from one point touching the bar on either side of what would be the center if we had an even number of bars. It continues in this manner until all the bars are included. If the second bar touched is past the center, it is called progressive wave winding. If it touches before the center it is retrogressive wave winding.

Q. 16. Why must the output of a generator be controlled, and how is it done?

A. We have noticed that the output of a generator is dependent upon the number of lines of magnetic force and the speed at which they are cut. Therefore, as the speed of the generator increases, the output increases, and as your batteries and ignition units are designed to carry so much current, they cannot take care of this overload. There are two ways of regulating the output of a generator, in order that it may deliver a constant supply of current at a given rate:

1. A third brush is placed on the armature in such a way that its position may be altered, so as to change the charging rate, as the output increases. The position may be either one-quarter, or one-half between the main brushes. The third brush is connected to a shunt in series with the field, and weakens the field as the speed increases. As it is moved toward the main brush adjacent to it, less current is collected by it, and the output is heavy. As it is moved away from the nearest main brush, it collects more current, and therefore weakens the field to the extent of causing the output to drop.

2. By placing a controlling or regulating resistance in the field circuit, which regulates the number of lines of magnetic force cut.

Q. 17. Name some generator troubles, and their cause?

A. 1. Low voltage generated due to:

(a) Armature troubles—
1. Speed too low controlled by engine.
2. Open armature and flashing at commutator.
3. Short circuited armature winding.

(b) Field trouble—
1. Field circuit open.
2. Field coil grounded or short circuited.

(c) Brush trouble—
1. Brush off neutral.
2. Brush off contact.

Note: Brush tension is always given by manufacturer.

(d) Generator sparks—
   1. Brushes off neutral.
   2. Brush tension low.
   3. Brushes sticking in holders.
   4. Brushes not trimmed.
   5. High mica
   6. Low mica.
   7. Soft brush causing duty commutator and sparking.
   8. Hard brush causing rough uneven commutator.
   9. Open armature coil.

(e) Generator overheats (proper temp. under 150 degrees F.).
   1. Commutator (anything causing sparking will cause overheating).
   2. Brush tension too great.
   3. Armature (overload causing heat, due to some external short circuit).
   4. Fields overheat (short circuit).

2. Heavy output.
   1. Regulator out of adjustment due to vibration.

CHAPTER LI

Storage Batteries

Q. 18. What is a battery?

A. When two dissimilar metals are placed partially submerged in an acid solution, which is capable of acting chemically upon one of them more than upon the other when they are connected by a wire, the combination constitutes a simple Voltaic cell. Correctly speaking, the word battery is applied to a number of such cells, although it is commonly applied to a single cell.

Q. 19. How many kinds of batteries are used, and what are the advantages and disadvantages of each?

A. There are two distinct types of cells or batteries,—the primary and secondary, the primary cells generally being dry cells, and in these the voltage falls rapidly, due to polarization from the chemical action, the active material being consumed, therefore, they cannot be used for ignition. The second set is comprised of secondary cells, accumulators or storage batteries, and their fundamental characteristic is that they can be recharged. The recharging being a conversion of one material into another, and in discharging the reverse taking place, causing a constant chemical action.

Q. 20. Name the two different types of storage batteries, and the advantages of each?

A. There are two different types, the Edison or alkaline, and the lead cell. The Edison cell has a very poor voltage regulation, although it is lighter and smaller.

Q. 21. How many types of lead cells are used?

A. There are two types, the Plante and Faure. The Faure is a heavy solid plate, while the Plante is a pasted plate. The Plante is more commonly used on account of lightness.

Q. 22. How are the pasted plates constructed?

A. The pasted plate has lead with 5 per cent antimony mechanically pressed into a grid, and is much stronger than the solid plate which is formed electrically. Lead peroxide (P Bo2) is pressed into the grid, and gives greater amperage with less weight than the solid plate. The negative plate is of a gray spongy lead.

Q. 23. Give a general description of a storage battery?

A. In order to give a clear description of a storage battery, we shall describe the Liberty battery. It is of the Plante lead plate type consisting of three positive and four negative plates to a cell, and has four cells capable of producing an E.M.F. (electric motive force) of 7.5 to 8.8 volts. There are certain structural differences incorporated in this battery to adapt it for aviation use. These plates are bound together by a lead lug, three positive plates and four negative plates making one element. The plates are separated from one another by thin pieces of wood, known as separators, and placed in a rubber jar resting on ridges about a half an inch from the bottom. The space left in the bottom is known as the mud cellar, and takes care of the gradual accumulation of sediment, which would cause a short circuit if it came into contact with the plates. The rubber jars containing the four elements are in turn encased in a strong wooden box. Just above the plates there is a Baffle plate of hard rubber, and as the jar is about an inch and a half higher than the plates an air chamber is formed which prevents the electrolyte (acid and water) from spilling out when the battery is inverted.

In the baffle plate there are several small holes to allow the electrolyte to seep in when filling.

Q. 24. What happens when a battery is allowed to discharge below normal?

A. Both plates become lead sulphate, which is a non-conductor, causing the plates to expand, short circuit, and warp, breaking the grids.

Q. 25. What are the general causes of battery troubles?

A. They are as follows:

(a) Freezing.
(b) Bad connections.
(c) Grounds.
(d) Impurities.
(e) Sulphation.
(f) Short circuited cells.
(g) Hardened negatives.
(h) Soft plates.

Q. 26. Explain how these troubles would be corrected?

A. (a) Freezing. The batteries will freeze at the following temperatures if the specific gravity is as specified below:

25° above zero	1050
15° above zero	1115
10° above zero	1140
0° above zero	1165
10° below zero	1190
20° below zero	1205
30° below zero	1220

Note: These temperatures to be corrected to 70° F. (if temperature is above 70° add one point for every three degrees. If below 70° subtract one point for every 3°.)

(b) Bad connections. They result from copper sulphate forming on the terminals; the remedy is to keep them clean, washing them with ammonia, and using vaseline or asphaltum paint as a preventative.

(c) Grounds. If the electrolyte is spilled, there is a chance of grounding. Therefore, the battery should be wiped thoroughly dry with a rag saturated with ammonia, after testing for specific gravity.

(d) Impurities. These consist of iron and copper sulphate, the iron resulting from the use of undistilled water, and the copper sulphate from deposits on the terminal dropping into the cell. The remedy is to clean the cell.

(e) Sulphation. It forms an insulation on the plates causing them to expand breaking the grids. The result of sulphation is a short circuited cell, and the remedy is never to let the battery run too low. If sulphation should set in a long slow charge from an external source should bring the battery back to normal.

(f) Short circuited cells. This comes from active material dropped into the mud cellar. Overcharging forces the active material out of the grids. The remedy is to never overcharge, and if by accident this should occur, clean the cells.

(g) Hardened negatives. These are caused by carrying electrolyte too low. Therefore, the plates must be always covered by the electrolyte. If the plates are removed they should be kept cool.

(h) Soft plates. They are the result of overcharging, and can be remedied by placing the plates between two boards and squeezing them in a vise. This will force the active material back into the grids, and at the same time force the plate itself back into shape.

Q. 27. What four rules govern the care and maintenance of storage batteries?

A. 1. Add nothing but pure water to the cells, and do it often enough to keep the plates covered.

2. Take frequent hydrometer readings.

3. Give the battery a special charge whenever the hydrometer readings show it to be necessary.

4. Keep the filling plugs and connections tight and the battery clean.

Q. 28. What precautions should be taken in mixing electrolyte?

A. 1. Use a glass, china, earthenware, or lead vessel (never metallic other than lead).

2. Carefully pour acid into the water, *never water into acid.*

3. Stir thoroughly with wooden paddle and allow it to cool before reading the gravity.

Q. 29. What is the object of charging a battery?

A. The acid absorbed by the plates during discharge, is during charge driven from the plates by the charging current and restored to the electrolyte. *No current from the charging source is ever stored in the battery.*

Q. 30. In what proportions should electrolyte be mixed?

A. It should be mixed 3¾ parts distilled water to 1 part of chemically pure sulphuric acid.

Note: Do not confuse the expression chemically pure (C. P.) with *full strength.*

Sulphuric acid, oil of vitriol has a specific gravity of 1.835 or 1.840, but the specific gravity is not always a measure of its purity. Sulphuric acid is heavier than water; therefore, the greater the proportion of acid contained in the electrolyte, the heavier the solution and the higher the gravity.

INDUCTION COILS AND DISTRIBUTORS

Q. 31. Why are induction coils necessary in connection with battery generator systems?

A. To cause the current to jump across a gap of one inch requires an extremely high voltage (about 50,000 volts) and as the voltage of the battery is very low (6 to 8 volts) it is evident that we must introduce some device into the circuit that will increase the voltage and consequently the *jumping distance.*

Q. 32. Describe the induction coil?

A. It consists of two separate and distinct coils, that are thoroughly insulated from each other. One has a few turns of heavy copper wire and is called the primary. The other consists of many thousands of turns of very fine copper wire, and is called the secondary. Both coils are wound around a bundle of soft iron wire called the "Core" from which they are carefully insulated. When the battery current flows through the primary coil, the core is magnetized and throws its magnetic influence through the turns of the secondary coil. The induced current depends upon:

(a) The strength of the field or (the number of magnetic lines of force it contains).

(b) The speed or rate of cutting or (the number of lines of force cut per second).

(c) The number of wires cutting the lines of force. In order to obtain a continuous discharge of sparks, and have this maximum density occur at the right moment, a set of breaker points is necessary. While these breaker points are not integral with the coil, their movement effects its operation.

Q. 33. Describe the condenser as used in conjunction with the induction coil?

A. When the breaker points open, breaking contact, it is necessary to reduce the spark to the lowest possible limits, in order to increase the life of the breaker points, and also in order to obtain as quick a break as possible. Therefore, the condenser is installed for the purpose of suppressing the spark between the breakers, and also to cause a sharp quick break in the primary circuit at the instant of the separation of the points. The intensity of the spark at the terminals of the secondary coil depends upon the quickness with which the break occurs, and if it were not for the condenser the length and intensity of spark would be greatly reduced. The condenser consists of alternate layers of paper and tinfoil, every other layer of tinfoil being connected to one side of the breaker and the remainder to the other.

Q. 34. Why is a distributor necessary, and how does it function?

A. After the high tension current is generated in the secondary winding, it must be transmitted to the proper cylinder at the proper time, and this is done through the medium of the distributor head. It is made of hard rubber, Bakelite or other insulating material with contact segments of brass interlaid and spaced at equal and proper intervals. A rotor arm directly connected to, or driven at the same speed as the camshaft (one-half engine speed) causes the high tension current to pass through these segments to the spark plug, through the medium of a high tension *lead*.

Q. 35. Describe the Liberty ignition system by tracing the current from its source to the plug.

A. The Delco (Dayton Engineering Laboratory Company) system as used on the Liberty engine is a single wire system. By this we mean that the negative side or (−) minus side of all units is grounded. To start the engine the switch

marked *L* (left) is moved outboard or to the *On* position. We do this, for there is less resistance in this switch. Either one, however, the right or left hand switch, could be used. The current leaves the positive side of the battery, flows through the ammeter, the ammeter showing a discharge. From the ammeter it flows through a lead to the primary binding post on either one of the distributor heads according to what switch is on (in this case the left one). It is then transmitted through the breaker points to the primary winding of the induction coil (the condenser being in series with the breaker points and coil). As it is passed through the primary coil, a high tension voltage is induced into the secondary (there is no electrical connection between these two windings). We now have high tension current, and this is caused by a contact point from the coil to the rotor in the distributor, to the segments and thence to the spark plugs, and returned by ground. When our engine reaches the proper speed, at which the generator may produce more current than the battery is delivering both switches are thrown on. This speed is anywhere from 700 to 800 R.P.M., and can be determined by watching the ammeter. It is safe to leave both switches *on* when the needle passes over zero on the charge side. The proper way is to open the throttle to 700 or 800 R.P.M.—then throw the other switch, if ammeter shows charge, it is all right; if not, open throttle until it does for test. If it takes more than 700 to 800 R.P.M. to show charge, we know that the regulator is not functioning properly. It can be adjusted by releasing the tension on the spring; however, it should not be adjusted unless one is thoroughly familiar with the operation. When both switches are *on*, the generator supplies both distributors and at the same time supplies the current to charge the battery. At full speed the ammeter should show from 4 to 5 amperes charge.

Q. 36. What should be done periodically in the line of inspections and adjustments to insure proper operation of the Liberty Ignition system?

A. 1. The battery should be flushed once a week and specific gravity tested. Remove vent plug, and fill each cell with distilled water to a height of 1 inch above the plates. Allow it to stand for a minimum of two minutes (not over five minutes), then remove all water in excess of what is required to just cover the plates. When the battery is fully charged, it should show a gravity of 1290 to 1310 degrees.

2. Examine all wiring, both low tension and high tension, for broken insulation; also see that terminals are firmly attached. (Note: Instead of removing wires from conduits they can be tested with a magneto bell apparatus or buzzer. By attaching each end of the lead to the apparatus, the bell or buzzer can be rung. This shows whether or not the lead is broken or shorted.)

3. Examine the surface of the distributor, particularly the path of the rotor brush and contact segments. Wipe out carbon dust with a soft rag, moistened with either alcohol, gasoline, or good metal polish.

4. Examine distributor shaft for lost motion. There should not be more than $\frac{1}{16}$-inch motion at the end of the rotor arm.

5. Check gap of each breaker. It should be taken with breaker block on wide lobe of the cam. There should be 10 to 13 thousandths (as shown by thickness gauge) clearance between them. If points are pitted they should be smoothed down on an oil stone

6. Examine brushes. If they are less than $\frac{1}{4}$ inch long, renew them. *Brushes do not require lubrication.*

7. Examine the wire leading from the field coils to the generator terminal connections. This wire should be kept clean and free from oil and dirt.

8. Examine the commutator and brushes in the generator. If it is burned or rough, polish it off with a piece of very fine sand paper. When the commutator shows a fine *blue* polished surface it is in good condition and should only be wiped clean with a soft rag.

9. It is important particularly in aircraft practice to see that all terminals are tight and above all clean. Oil, water and other liquids if allowed to remain on the insulation will saturate it, in time causing a short. Never try to adjust any apparatus that you do not fully understand.

CHAPTER LII

Magnetos

Q. 37. Under what two principles do magnetos operate?

A. Magnetos operate under the same principles that govern the operation of generators.

1. If a conductor or a number of conductors are placed in a magnetic field, and revolved so as to cut the lines of force a voltage will be generated.

2. If a conductor or a number of conductors are placed in a magnetic field, and the field strength varied so as to cut the windings, a voltage will also be generated.

The first principle governs the operation of all shuttle wound armature types of magnetos, such as Bosch, Berling, Sims, and others. The second principle governs the operation of the Dixie, and when applied to magnetos is known as the Mason principle.

Q. 38. Describe the ordinary shuttle wound armature magneto?

A. It consists of two permanent magnets (to supply the field) and iron core, upon which is wound both the primary and secondary windings, this assembly confusing the armature. In series with the primary winding are a set of breaker points and a condenser, the operation of which we have already studied. A brush collects the high tension current from a collector ring. It is transmitted through a safety gap to a high tension pencil, and thence to the distributor.

Q. 39. Describe the Dixie type of magneto?

A. Like the ordinary shuttle type magneto the Dixie has

two permanent magnets to supply the field. Two pole pieces mounted on a brass shaft are in contact with the north and south poles of the magnets. The primary and secondary windings are placed between the magnets and above the rotary pole structure. The condenser is mounted above the windings and the current is carried to the distributor through a high tension pencil as in all other magnetos.

Q. 40. What advantages has the Dixie over all other types of magnetos?

A. The windings of the Dixie magneto can be moved back and forth over the pole structures instead of advancing and retarding the breaker points; therefore, we receive the maximum density of spark at all speeds. This type of magneto can also use a four ring cam and can therefore be run at half speed of the other types, which allows a longer life and less trouble. The various working parts of a Dixie are very accessible and easily replaced.

Q. 41. What points must be watched carefully for the maintenance of Dixie magnetos?

A. The bearings should be lubricated after 1000 miles of flying, with a few drops of light oil. The breaker arm should also be lubricated after every 1000 miles, this oil being applied with a tooth pick. The proper clearance of the breaker points when separated should be 0.020 inch; these platinum contacts should be kept clean and properly adjusted. The distributor block should be removed occasionally and wiped free from carbon dust. Spark plugs used with this magneto should have a gap of 0.020 inch. The distributor absorbs moisture easily, and as a consequence will short when damp. Great care should be exercised in order to prevent this, and in the event it should short due to its absorbing moisture it can be dried out in an oven.

Q. 42. How would you time a Dixie magneto?

A. We have seen from our study on ignition that the time of firing the plug is most important; therefore, the proper timing of the magneto is very important. The setting must be made in accordance with the valve timing and other characteristics of the engine it is to be used on. The following method must be carried out:

1. Rotate the engine until piston in No. 1 cylinder is on upper dead center. Then reverse until piston is on firing position advanced. The rotor should be in the center of No. 1 segment and the breaker points should be just breaking. Secure the magneto to its base and bolt coupling together. Connect each segment in the direction of rotation to the spark plugs in the cylinders in the proper order of their firing. It is well to check over timing, in order to be sure that it is correct.

Q. 43. How would you synchronize two Dixie magnetos?

A. That the two magnetos fire simultaneously is just as important as the timing of the magneto. The following method should be used:

1. Remove the covers from the magnetos.
2. Disconnect the primary wire from its binding post on both magnetos.

Note: This will be found on the right hand side of the magneto.

3. Connect each primary wire to a buzzer or light set, and ground this set.
4. Rotate motor and note whether the lights, light, or buzzers work absolutely together. Note: If in an emergency buzzers or lights cannot be procured, cigarette papers can be used. They should be inserted between the breaker points and an equal tension should remove them if both magnetos are breaking together.

CHAPTER LIII

Gasoline Carburetion and Carburetors

Q. 1. Why is the study of gasoline and carburetors a very important matter in connection with aircraft engines?

A. We have seen before that an internal combustion engine is a mechanical device for the conversion of the heat energy contained in gasoline to mechanical work. Therefore, the study of gasoline, its derivation, the proper mixing with air, and the apparatus with which we accomplish this mixing is very important.

Q. 2. What differences in motor operation are caused by fuel and carburetors?

A. They are:

1. Differences in idling (which are important for maneuvering).
2. Differences in acceleration (also necessary for maneuvering).
3. Differences as to steady load conditions, although spark and gas may be set.
4. Differences in altitude.

Therefore, a carburetor properly designed for use on aircraft engines must cause the engine to idle well and evenly. Must accelerate quickly but not spasmodic; must cause the engine to maintain an even speed under load, and should have some device attached in order that the pilot may compensate for atmospheric changes at high altitudes.

Q. 3. What mechanical differences must be noted in designing a carburetor for aircraft use?

A. 1. *Clogging.* It must not clog easily from sand or dust or other small particles of solid matter, or gum and wax from gasoline itself.

Note: This may also be remedied by filtering fuel thru fine screen and using a sediment trap on the line.

2. *Spilling.* Gasoline should never spill from float chamber or valve, due to engine vibration. (This is a source of danger on account of fire.)

3. *Filtering.* All aircraft are now maneuvered at excessive angles, therefore, the carburetor should function at any angle.

4. *Resistance to Backfire.* Air valves in carburetors should be placed in such a manner that in the event of a backfire, the valve will not be blown shut. If the valve should be blown shut the carburetor will be broken off at the flange.

Q. 4. How is gasoline procured and how can one tell good gasoline from poor?

A. Gasoline is procured from crude petroleum, and petroleum gas, and it is distilled in two ways.

1. Natural gas is compressed at a constant temperature, and condensed by being led through pipes surrounded by coils of water, known as the casing head process.

2. Gasoline is distilled from crude petroleum by the fractional distillation process. The petroleum is boiled in a very large tank, and the various gases are led through pipes surrounded by coils of water to a number of smaller tanks. The gases passing off first form the best grade of gasoline, and so on down the line until we have heavy lubricating oil, and residue. From crude petroleum we get 8 to 10 per cent high grade volatile gasoline, 70 to 80 per cent in light oils such as kerosene and light lubricating oils. Heavy oil such as 600 W and residue forming 5 to 9 per cent. Casing head

gasoline is a very volatile liquid showing a reading from 80° to 86° on the Baume hydrometer. It is best for engine use but the cost is prohibitive. It can be seen that the gasoline distilled from petroleum will contain a certain amount of kerosene and other objectional liquids, but still it is used in aircraft engines. This gasoline shows a reading of from 60° to 70° on the Baume hydrometer. Although the Baume reading will give a fair idea of the quality of the fuel, it is better in testing to redistill it and note the temperatures of the boiling points of its various constituents. This is known as fractional distillation and by plotting a curve, temperature against the quantity, the quality of the fuel can be judged.

GASOLINE, VARIOUS GRADES, INSPECTION AND TESTS OF

Q. How many grades of gasoline are used by the United States Navy

A. Three grades, as follows:

(A) Fighting aviation gasoline.

(B) Domestic aviation gasoline.

(C) Motor gasoline.

Q. What are the detail requirements of the various grades of gasoline?

A. (a) Grade A, fighting aviation gasoline, shall conform to the following requirements:

1. Color. The color shall be water white. If specifically requested by the department, this grade shall be colored red.

2. Doctor test. The gasoline shall yield a negative doctor test.

3. Corrosion test. The gasoline when subjected to the corrosion test shall show no gray or black corrosion, and no weighable amount of deposit when evaporated in a polished copper dish.

4. Unsaturated hydrocarbons. Not more than 1 per cent of the gasoline shall be soluble in concentrated sulphuric acid.

5. Acid heat test. The gasoline shall not increase in temperature more than 10° F.

6. Volatility and distillation range. When 5 per cent of the sample has been recovered in the graduated receiver, the thermometer shall not read more than 65° C. (149° F.) nor less than 50° C. (122° F.).

When 50 per cent has been recovered in the receiver the thermometer shall not read more than 95° C. (203° F.).

When 90 per cent has been recovered in the receiver the thermometer shall not read more than 125° C. (257° F.).

When 96 per cent has been recovered in the receiver the thermometer shall not read more than 150° C. (302° F.), and the end point shall not be higher than 165° C. (329° F.).

At least 96 per cent shall be recovered as distillate in the receiver from the distillation.

The distillation loss shall not exceed 2 per cent when the residue in the flask is cooled and added to the distillate in the receiver.

7. Acidity. The residue remaining in the flask after the distillation is completed shall not show an acid reaction.

(b) Grade B, domestic aviation gasoline, shall conform to the following requirements:

1. Color. The color shall be water white.

2. Doctor test. The gasoline shall yield a negative doctor test.

3. Corrosion test. The gasoline, when subjected to the corrosion test shall show no gray or black corrosion, and no weighable amount of deposit when evaporated in a polished copper dish.

4. Unsaturated hydrocarbons. Not more than 1 per cent of the gasoline shall be soluble in concentrated sulphuric acid.

5. Acid heat test. The gasoline shall not increase in tem-

perature more than 10° F. when subjected to the acid heat test.

6. Volatilty and distillation range. When 5 per cent of the sample has been recovered in the graduated receiver, the thermometer shall not read more than 75° C. (167° F.), nor less than 50° C. (122° F.).

When 50 per cent has been recovered in the receiver the thermometer shall not read more than 105° C. (221° F.).

When 90 per cent has been recovered in the receiver the thermometer shall not read more than 155° C. (311° F.).

When 96 per cent has been recovered in the receiver the thermometer shall not read more than 175° C. (347° F.).

The end point shall not be higher than 190° C. (374° F.).

At least 96 per cent shall be recovered in the receiver from the distillation.

The distillation loss shall not exceed 2 per cent when the residue in the flask is cooled and added to the distillate of the receiver.

7. Acidity. The residue remaining in the flask after the distillation is completed shall not show an acid reaction.

(c) Grade C, Motor Gasoline, shall conform to the following requirements:

1. Distillation range. When the first drop has been recovered in the graduated receiver, the thermometer shall not read more than 60° C (140° F.).

When 20 per cent has been recovered in the receiver the thermometer shall not read more than 105° C. (221° F.).

When 50 per cent has been recovered in the receiver the thermometer shall not read more than 140° C. (284° F.).

When 90 per cent has been recovered in the receiver the thermometer shall not read more than 190° C. (374° F.).

The end point shall not be higher than 225 C.° (437° F.).

At least 95 per cent shall be recovered as distillate in the receiver from the distillation.

METHODS OF INSPECTION, TESTS, ETC.

(a) All gasoline shall be inspected before acceptance. Several samples consisting of at least 100 cc. each shall be taken from each shipment. These samples immediately after drawing shall be retained in a clean, absolutely tight closed vessel and the sample for test taken from the mixture directly into the test vessel.

(b) Color. One hundred cubic centimeters of the gasoline contained in a 4-ounce sample bottle or a graduate shall be compared to a similar column of distilled water.

c. Doctor test.

1. Preparation of reagents—Sodium plumbite or "doctor solution." Dissolve approximately 125 grams of sodium hydroxide (NaOH) in a liter of distilled water. Add 60 to 70 grams of litharge (PbO) and shake vigorously for 15 to 30 minutes, or let stand with occasional shaking for at least a day. Allow to settle and decant or siphon off the clear liquid. Filtration through a mat of asbestos may be employed if the solution does not settle clear. The solution should be kept in a bottle tightly stoppered with a cork.

2. Sulphur. Pure flowers of sulphur.

3. Making of test. Shake vigorously together two volumes of gasoline and one volume of the "doctor solution" (10 cc. of gasoline and 5 cc. of "doctor solution") in an ordinary test tube; or proportional quantities in a 4-ounce oil sample bottle may conveniently be used. After shaking for about 15 seconds, a small pinch of flowers of sulphur should be added and the tube again shaken for 15 seconds and allowed to settle. The quantity of sulphur used should be such that practically all of the sulphur floats on the surface separating the gasoline from the "doctor solution."

4. Interpretation of results. If the gasoline is discolored, or if sulphur film is so dark that its yellow color is noticeably masked, the test shall be reported as positive and the gasoline

condemned as "sour." If the liquid remains unchanged in color and if the sulphur film is bright yellow or only slightly discolored with gray or flecked with black the test shall be reported negative and the gasoline considered "sweet."

(d) Corrosion test.

1. The apparatus used in this test consists of a freshly polished hemispherical dish of spun copper, approximately 3½ inches in diameter.

2. Place 100 cc. of the gasoline to be examined in the dish, and place the dish in an opening of an actively boiling steam bath so that the steam comes in contact with the outer surface of the dish up to the level of the gasoline. Leave the dish on the steam bath until all volatile portions have disappeared.

3. Interpretation of results. If the gasoline contains any dissolved elementary sulphur the bottom of the dish will be colored gray or black.

If the gasoline contains undesirable gum-forming constituents, there will be a weighable amount of gum deposited on the dish.

Acid residues will show as gum in this test.

(e) Unsaturated hydrocarbons.

1. The apparatus used in this test consists of a modified Babcock bottle. The neck is calibrated for the volume of 10 cc., subdivided in 0.2 cc. intervals. The bottle shall contain approximately 30 cc. up to the base of the neck and shall be approximately 6¾ inches high over all.

2. Ten cubic centimeters of the gasoline to be tested is run from a pipette into a clean, dry bottle, cooled for a minute or two by immersing in ice water, and then 20 cc. of commercial 66° sulphuric acid (containing approximately 93.19 per cent H_2SO_4) is poured in from a small graduate. Care should be taken that the acid runs quietly down the side of the bottle, instead of splashing onto the surface of

the gasoline. A rubber stopper is then placed in the bottle and the contents are shaken, first slowly, then vigorously with a rotary motion for several minutes. The gasoline and the acid are separated by either one of the following two methods:

(f) Gravity separation. Sulphuric acid is added to the contents of the bottle until the surface of the liquid is about level with the upper graduation mark on the neck of the bottle. The mixture is then set aside and allowed to stand overnight, when practically complete separation is effected.

(g) Centrifugal separation. The stoppered bottle is placed in a suitable centrifuge and revolved for two or three minutes at a speed of 500 to 1,000 r.p.m. Sufficient acid is then added to bring the level up to the lower graduation mark and the contents are again centrifuged to complete the separation. More acid is then added to bring the column to the upper graduation mark, after which the residual volume of the gasoline is read.

(h) Acid heat test.

1. Apparatus. One 1-pint glass bottle provided with a ground-glass stopper.

One 50 cc. graduate.

One thermometer graduated in 1° divisions. (The thermometer used in taking pour test of lubricating oils is perfectly satisfactory).

2. Method of testing. Pour 150 cubic centimeters of the gasoline into the pint bottle.

Pour 30° cubic centimeters of 66° commercial sulphuric acid, containing approximately 93.19 per cent H_2SO_4 into the graduate.

Bring both solutions to the room temperature and note the temperature.

Pour the acid into the bottle containing the gasoline, insert ground-glass stopper, and shake vigorously for 2

minutes. (Avoid warming the bottle from the heat of the hands).

Allow to stand for 1 minute, then remove stopper, insert the thermometer and note the temperature of the gasoline.

The difference between the two readings represents the raise in degrees.

(i) *Flash test.* This test is the same as that specified in the methods of testing burning oils.

(j) *Spot test.* Place 5 drops of the oil on clean white filter paper and allow the liquid to evaporate at room temperature, away from direct sunlight. There should be no oily spot left after 30 minutes.

(k) *Distillation test.* Apparatus. 1. Distillation flask and support.

The flask used shall be the standard 100 cc. English flask, described in the various textbooks on petroleum. Dimensions are as follows:

DIMENSIONS	CENTIMETERS	TOLERANCE	INCHES	TOLERANCE
Outside diameter of bulb....	6.5	±0.10	2.56	±0.04
Inside diameter of neck.....	1.6	±0.05	0.63	±0.02
Length of neck..............	15.0	±0.20	5.91	±0.08
Length of vapor tube.......	10.0	±0.20	3.94	±0.08
Outside diameter of vapor tube.....................	0.6	±0.05	0.24	±0.02

Position of vapor tube, 9 cm. (3.55 inches) above the surface of the gasoline when the flask contains its charge of 100 cc. The tube is approximately in the middle of the neck, and is set at an angle of 75° from the perpendicular. The observance of the prescribed dimensions is considered essential to the attainment of uniformity of results.

The flask shall be supported on a piece of asbestos board 6 inches square having a circular opening $1\frac{1}{4}$ inches in

diameter; this means that only this limited portion of the flask is to be heated. The use of wire gauze is forbidden.

(l) *Thermometer.* The thermometer shall be made of selected enamel-backed tubing, having a diameter between 5.5 and 7 mm. The bulb shall be of Jena normal or Corning normal glass; its diameter shall be less than that of the stem, and its length between 10 and 15 mm. The range shall cover 0° C. (32° F.) to 270° C. (518° F.) with the length of the graduated portion between the limits of 210 to 250 mm. The point marking a temperature of 35° C. (95° F.) shall not be less than 110 mm. nor more than 135 mm. from the bottom of the bulb.

When the thermometer is made according to the Centigrade scale it shall be graduated in 1° intervals. Each tenth degree shall be numbered and each fifth degree shall be distinguished by a larger mark.

When made according to the Fahrenheit scale, it shall be graduated in 2° intervals, each twentieth degree being numbered and each tenth degree being distinguished by a larger mark.

The scale shall be graduated for total immersion. The accuracy shall be within about 0.5° C. (1.0° F.). The space above the meniscus shall be filled with an inert gas, such as nitrogen, and the stem and bulb shall be thoroughly aged and annealed before being graduated.

All materials and workmanship shall be the best.

(m) *Condenser.* The condenser shall consist of a thin-walled tube of brass or copper ½ inch internal diameter and 22 inches long. It shall be set at an angle of 75° from the perpendicular and shall be surrounded with a cooling jacket of the trough type. The lower end of the condenser shall be cut off at an acute angle and shall be curved down for a length of 3 inches. The condenser jacket shall be 15 inches long.

(n) *Graduate* The graduate shall be of the usual type with a pressed or molded base and a lipped top. The graduated portion shall be for the quantity of 100 cc. It shall be numbered from the bottom up at intervals of 10 cc. Markings shall be for single cubic centimeters and each fifth mark shall be distinguished by a longer line.

The length of the graduated portion shall be not less than 7 inches nor more than 8 inches. The distance from the upper graduated mark to the rim shall be not less than $1\frac{3}{4}$ inches nor more than $1\frac{1}{4}$ inches.

(o) *Source of heat.* The source of heat in distilling gasoline may be a gas burner, an alcohol lamp, or an electric heater.

(p) *Procedure and details of manipulation in conducting distillations.* (1) The condenser trough is filled with water containing a liberal portion of cracked ice, so that the temperature is not lower than 32° F. nor above 40° F. The condenser tube is swabbed to remove any liquid remaining from a previous distillation.

(2) One hundred cubic centimeters of gasoline is measured at a temperature of 60° F. into the clean, dry Engler flask from a 100 cc. graduate. The same graduate is used as a receiver for distillates without any drying. This procedure eliminates errors due to incorrect sealing of graduates and also avoids the creation of an apparent distillation loss due to the impossibility of draining the gasoline entirely from the graduate.

(3) The above-mentioned graduate is placed under the lower end of the condenser tube so that the latter extends downward below the top of the graduate at least 1 inch. If the room temperature be above 80° F. the receiving graduate shall be placed in a bath maintained at a temperature not less than 65° F. nor more than 75° F. The condenser tube shall be so shaped and bent that the tip can touch the wall of the graduate on the side adjacent to the condenser box.

This detail permits distillates to run down the side of the graduate and avoids disturbance of the meniscus caused by the falling of drops. During the distillation the graduate is moved occasionally to permit the operator to ascertain that the speed of distillation is right, as indicated by the rate at which drops fall. The proper rate is from 4 cc. to 5 cc. per minute, which is approximately two drops a second. The top of the graduate is covered, preferably by several thicknesses of filter paper or blotting paper, the condenser tube passing through a snugly fitting opening. This minimizes losses due to circulation of air through the graduate and also excludes any water that may drip down the outside of the condenser tube on account of condensation on the ice-cooled condenser box.

(4) A boiling stome (a piece of unglazed porcelain or other similar material not exceeding $\frac{1}{4}$ inch in any dimension) is dropped into the gasoline in the Engler flask. The thermometer is equipped with a well-fitted cork and its bulb covered with a thin film of absorbent cotton (preferably the long-fibered variety used for surgical dressing). The quantity of cotton used shall be not less than 0.005 nor more than 0.010 gram (5 to 10 mgm.). The thermometer is fitted into the flask with the top of the bulb just below the lower level of the side neck opening. The flask is connected with the condenser tube by means of a well-fitted cork or stuffing box. The vapor tube must extend at least $\frac{1}{4}$ inches into the condenser tube.

(5) Heat must be so applied that the first drop of the gasoline falls from the end of the condenser tube in not less than 5 nor more than 10 minutes. The initial boiling point is the temperature shown by the thermometer when the first drop falls from the end of the condenser tube into the graduate. The amount of heat is then increased so that the distillation proceeds at a rate of from 4 cc. to 5 cc. per minute. The thermometer is read as each of the selected percentage

marks is reached. The maximum boiling point or end point is determined by continuing the heating until the column of mercury reaches a maximum and then starts to recede consistently.

(6) Distillation loss is determined as follows: The condenser tube is allowed to drain for at least 5 minutes after heat is shut off, and a final reading taken of the quantity of distillate collected in the receiving graduate. The distillation flask is removed from the condenser and thoroughly cooled as soon as it can be handled The condensed residue is poured into a small graduate or graduated test tube and its volume measured. The sum of its volume and the volume collected in the receiving graduate, subtracted from 100 cc., gives the figure for distillation loss.

(q) *Acidity.* The cooled residue from the distillation flask is collected in a test tube and its volume noted. Three volumes of distilled water are added and the tube is shaken thoroughly. The mixture is allowed to separate and the aqueous layer is removed to a clean test tube by means of a pipette and 1 drop of a 1 per cent solution of methyl orange is added. No pink or red color shall be formed.

PACKING AND MARKING OF SHIPMENTS

(7) Gasoline shall be delivered in containers in conformity with the issue of Navy Department Specification 42D2 in effect at the date of opening of the bids. Each container shall be marked with the grade of gasoline (fighting aviation, domestic aviation, or motor), quantity contained, contract or order number, and name of the contractors.

Q. 5. What is a carburetor?

A. A carburetor is a device for mixing air and gasoline in the proper proportions (about 15 or 16 parts of air to one part of gasoline) in order that it may form an explosable mixture.

Q. 6. Describe some early forms of carburetors or vaporizors.

A. These early forms of carburetors or vaporizors were very crude and cumbersome, the mixing of the gasoline and air being accomplished in three ways.

1. The air stream was passed over the surface of the liquid, this being known as a surface carburetor (now obsolete).

2. The air was passed through loosely placed absorbent material saturated with gasoline, this being known as the "wick" carburetor (also absolete).

3. The air was passed directly through the gasoline, this being known as the "bubbling" carburetor.

These old type carburetors functioned fairly well on low speed engines, for they used a gasoline high in volatility. The modern high speed engine is required to use low grade fuel, so the old type of carburetor has given way to the device known as the "spraying carburetor," which reduces the fuel to a spray by the suction effect of the entering air stream drawing it through a small opening.

Q. 7. Describe the modern float feed carburetor.

A. The modern "spraying" carburetor is provided with two chambers; one the mixing chamber, through which the air stream passes mixing with the gasoline, and the other in which a constant level of fuel is maintained by a simple float and float valve mechanism. A jet or standpipe is placed in the middle of the mixing chamber to carry the fuel, and the object of the float is to maintain that level of gas that will not overflow when the motor is stopped.

Q. 8. What is one of the hard problems that effect carburetion?

A. It is generally believed that the flow of gasoline and air increase proportionately when the motor "is opened up"

and the speed increased. But such is not the case, for the flow of gasoline increases faster than the flow of air. Most carburetors have automatic valves and other mechanical devices to compensate for this, but so far the Zenith carburetor regulates the flow of gasoline and air in the simplest manner, and therefore is used extensively on aircraft engines.

Q. 9. Describe the Zenith carburetor.

A. To best illustrate the principle of the Zenith carburetor, we must first consider the elementary type of carburetor, one with two chambers, the float chamber and the mixing chamber. We have seen that as the suction increases, the flow of gasoline also increases, but to a greater extent than the flow of air. By using a number of auxiliary air valves we can dilute this rich mixture by adding air, but the trouble caused by these moving parts can be eliminated by the use of the compound nozzle and compensating jet. With our first carburetor, with the single jet, which causes the mixture to grow richer and richer as the speed increases, is combined another apparatus integral with it which causes the mixture to grow leaner as the speed increases. These two devices combined in one carburetor balance, which gives us a desirable mixture (15 to 16 parts of air to one of gas constantly). This second jet, causing the mixture to grow lean as speed increases is known as the compensating device. A certain fixed amount of gasoline (determined by the size of the opening in the float chamber) is permitted to flow by gravity into a well open to the atmosphere. The suction at the top of the jet in the mixing chamber has no effect upon the flow through this opening or compensator in the float chamber, for the suction is destroyed by the well open to the atmosphere. Therefore, when motor suction increases drawing more air through the carburetor, the amount of gasoline remains the same, consequently the mixture grows

poorer. The Zenith carburetor is therefore a combination of two carburetors in one. One in which the mixture grows rich, and one which grows poor as speed increases; therefore, from the cranking of the engine to its highest speed there is a constant ratio of air and gasoline to supply efficient combustion. In addition to this compound, nozzle or compensating device, the Zenith carburetor is equipped with a starting and idling device. There is a priming hole above the mixing chamber just at the edge of butterfly valve, where the suction is greatest when this valve is closed or very slightly open. The gasoline is drawn up by the suction through the priming hole and mixed with the air rushing by the butterfly valve giving an ideal or rich mixture for starting and idling. At high speeds when the butterfly valve is opened, this idling device ceases to operate, because the gasoline in this well is drawn through the cap jet.

Q. 10. What three parts have to be changed in the Zenith carburetor in order to change its adjustment?

A. They are choke tube or venturi tube, main jet and compensator. The size number of each of these parts is stamped on the end of each part, and all three parts together form the "setting."

Q. 11. How are chokes of venturi tubes numbered?

A. The chokes are numbered in millimeters according to the size of their smallest diameter.

Q. 12. How are jets and compensators numbered?

A. The jets and compensators are numbered in hundredths of a millimeter. A one hundred jet has a one millimeter hole, and is smaller than a one hundred and five jet. They are graded by five hundredths of a millimeter apart.

Q. 13. What particular fact should be borne in mind when altering the "setting" of the Zenith carburetor?

A. When engines are regularly equipped at the factory with the Zenith carburetor, it is seldom necessary to change the factory setting, for these have always been determined by experts after conducting many tests. There is no moving part in this carburetor that affects the mixture, so it is always reasonable to assume that trouble may be caused by dirt and water in carburetor, by some one tampering with its setting, or by some disarrangement of adjustment of ignition, valve operation, or other mechanism.

Q. 14. How should a test be made to ascertain whether or not the setting is incorrect.

A. The following tests should be made in order first determining whether the faults lie in the choke, then the main jet, and then the compensator.

1. Choke. This is a venturi tube with an angle of 10° on the discharge side, and is of a streamline shape that allows the maximum flow of air without any eddies and with the least resistance. This choke is held in place with a single screw and easily removed, providing the butterfly valve (throttle) is not in place.

(a) If pick up is defective and cannot be bettered with a larger compensator. If motor does not run smooth at idling speed. If motor shows a tendency to load up at high speeds and misses, our choke tube is *too large.*

(b) If the motor does not take a full charge with open throttle, and if although "pick up" is good maximum R.P.M. is not obtained, the choke tube is *too small.* Remember that when a larger choke tube is used, a greater amount of air is admitted and the mixture grows leaner.

2. Main jet. It is easily removed after unscrewing the lower plug. The influence of the main jet is mostly felt at high speeds.

(a) Main jet too large. While running at high speed our engine will have all indications of a rich mixture.

(b) Main jet too small. The mixture will be lean at high speeds, and the maximum R.P.M. will not be received.

3. Compensator. It is easily removed after unscrewing the lower plug. The influence of the compensator is noted generally at *low speeds.* A pull under a load generally shows whether or not the compensator is of the correct size.

(a) Compensator too large. Too rich a mixture on a hard pull will be noted in operation, or the same indications of a rich mixture at high speeds.

(b) Compensator too small. Our engine will show a lean mixture, missing and backfiring.

4. Idling devices. This device differs in each model of carburetor. Before adjusting this device, it must be remembered that many factors prevent good idling. Some are:

1. Poor gaskets
2. Loose valve stems
3. Pitted valves

} creating air leaks.

4. Leaky plugs or primers.
5. Spark plug gap *too close.*
6. Load too light.
7. Too much spark advance.
8. Spark too late.

(a) If idling device is too small. It will be impossible to obtain the proper mixture, except by turning the idling screw all the way in. (In this event use a larger idling device.)

(b) If idling device is too large. It will be impossible to obtain the proper mixture except by turning the idling screw out as far as possible. (In this event use a smaller idling device.)

Q. 15. Name some carburetor or gasoline troubles and their remedy.

A. 1. If engine starts hard.

(a) Be certain that throttle is opened a trifle.

2. See if there is fuel in carburetor. (This can be done by depressing the needle valve in the float chamber. If float chamber is empty, examine supply tank. If empty fill with gasoline; if it has a sufficient amount of fuel, examine pipes for dirt and other matter that may be "stopping up" the line.

3. Check up ignition (take off a spark plug wire and hold it about $\frac{1}{8}$ inch from the plug; if no spark is received check up ignition.

Note: (The above examinations will show whether or not you have fuel for your engine, and the proper spark to ignite it.) In the event that we have both, look for further trouble as follows:

Note: The following troubles cannot be termed carburetor troubles, but as a general rule the carburetor is blamed for troubles emanating from other sources.

4. Leaks in the manifold or its connections. These leaks are generally found at the joints, and are usually caused by faulty gaskets, by the absence of gaskets, or by the failure of the joints to come squarely together.

Note: (Gaskets should be made of some soft compressible material) preferably a good gasket paper. Rubber should never be used on a fitting, holding gasoline.) In rare cases a manifold will leak air, due to a flaw in the casting.

5. Worn valve stems and guides. This is a trouble peculiar to old engines, and as a rule is hard to find. In the case that no leaks are found in the manifold or its connections, an engine still gives trouble from too much air, test valve stems and guides. Remember an air leak, however small it may seem to be, will have a great effect on engine starting, and operation, at low speeds.

6. Priming. After the above has been done, remove spark plugs and pour a few drops of gasoline in each cylinder. If the motor starts, but runs just long enough to burn up the priming charge, see if your idling device has not been plugged with dirt.

7. When the engine does not idle well. Before adjusting the carburetor it should be remembered, that in order to obtain good results in idling, the engine must be in good condition, and in perfect adjustment. Ignition must be strong and valves must seat good and have proper clearance. All cylinders must have equal compression and there must not be any air leaks however small.

Note: Never adjust the carburetor unless the engine is warm.

If mixture is rich while idling, it can be noted by missing and heavy gases coming from exhaust. Screw out on idling device until engine runs smooth.

If mixture is lean while idling it will be noted by missing, back-firing, and in some cases stopping. Screw in on adjusting device until regular running is obtained.

Note: When making an idling adjustment have it on the "rich side." i.e., have the screw adjusted to such a point that a slight turn in would result in a rich mixture.

8. When "pick up" is defective, it may be caused by any of the following: Mixture too rich, or too lean, spark plug points too far apart, manifold too large, or having a rough interior. If our adjustment is lean and the throttle is pulled open suddenly the engine will hesitate, spitback, and stop. (Try a larger main jet.) If carburetor is adjusted rich, and the throttle is pulled open suddenly the engine will hesitate and then run in an irregular manner. (Try a smaller main jet or compensator.) If changing jets does

not correct matters then change the choke, selecting jets accordingly.

Note: The only time a knock can ever be caused by a carburetor, is when an engine is pulling under a heavy load at low speeds; this knock is due to too lean a mixture.

Q. 16. What are the causes of leaking carburetors, and how can it be remedied?

A. A carburetor leaks fuel, it will be noted when gasoline is found to be dripping from the carburetor. In this event the carburetor should be removed from the engine and carefully examined as follows:

The bottom plugs, filter plugs, channel screws and cap jet; there are fibre washers under each of these that may have become defective, and they can be easily replaced with new ones.

Leaking carburetors are sometimes caused by some disarrangement within the float chamber. Before attempting to regulate or change the level of the fuel in the float chamber the mechanician should be satisfied that the leakage is due to this fault. Remove the float and shake it to determine whether or not any fuel has leaked into it. If so, submerge the float in boiling water. This will vaporize what fuel has leaked into the float, and at the same time locate the hole, as the fuel will come out at that place, causing bubbles to appear. When soldering the float only heat it to the point that is necessary in order to solder it, and use only enough solder to plug the hole, for if it is heated too hot the float will be damaged beyond repair, and if too much solder is used it will lose its buoyancy. Dirt or other foreign matter under the seat of the needle valve will also cause leakage. This can generally be remedied by twisting the needle, while alternately raising and lowering it. Leakage may also be caused by valve lever weights wearing flat. By reversing these members, this trouble can be remedied.

Q. 17. How should a carburetor be cleaned?

A. Most carburetor troubles are caused by water in the gasoline. The quickest way to remedy this trouble is to drain the carburetor. When the jets become clogged with dirt, there is a possibility of cleaning them by running the motor fast, i.e., accelerating a few times from idling to full speed. If the carburetor is so dirty that the jets have to be removed, they can be cleaned by air, or by a soft piece of wire (*never use a cutting tool or any object that will burr them or change their size.*

Note: The straining of the gasoline will do away with most troubles caused by dirt; however, some poor grades of gasoline contain some amount of wax and gum that will cause trouble at times.

CHAPTER LIV

Aircraft Engine Troubles

Q. 1. How are aircraft engine troubles located?

A. The first step toward the location of engine trouble is to thoroughly familiarize yourself with engine construction, that is learn each part, its function, and its relation to other parts. Trouble must be found through a process of elimination. The engine can be divided into two classes, the structure itself, which includes the crankcase, bearings, crankshaft, camshaft, connecting rods, pistons, cylinders, valves and their operating gear; and the auxiliaries which include the ignition system, the cooling system, the gasoline supply and vaporizing devices, and the lubrication system. These various appliances are so closely related to one another that the defective action of any one may interrupt the operation of the entire engine. Some of the parts are more important than others, but each one is essential and its faulty operation (especially the auxiliaries) will show up soon.

Q. 2. How would you divide or classify engine troubles?

A. Troubles can be classified in the following way:

1. Those that cause a complete stoppage.
2. Those that cause missing and poor operation.
3. Those that cause noisy operation or *knocking*.
4. Those that cause loss of power and overheating.
5. Failures to start.

Q. 3. Name some troubles that would cause a complete stoppage, their symptoms and remedy?

A. Troubles that cause complete stoppage can in turn be divided into two classes; troubles originating within the

engine or structure, and troubles originating within the auxiliaries.

1. Structure troubles that cause complete stoppages are generally breaking of parts, and are easy to find. The breaking of a crankshaft, camshaft, connecting rod, cylinder, piston, or the like will cause stoppage.

2. Auxiliary troubles that cause stoppage are not as easily found, therefore, we shall incorporate the most important ones in chart form.

Note: It should be remembered that if a part should break, we must not jump at conclusions, and say that the trouble originated in that particular part, for such is not the case. For example, a crankshaft breaks, due to seizing at one particular bearing. It is evident then, that this bearing was not receiving oil. We must then trace our trouble to the oil passage, and see whether or not it was a broken lead or a plugged outlet.

Auxiliary troubles that cause stoppage

TROUBLE	SYMPTOM	REMEDY
Engine not receiving gasoline	No gasoline in carburetor	Fill tanks if empty Turn on valve if off Clean pipes Clean out air vent in gravity tank
Engine not receiving gasoline	Gas in carburetor but not getting to engine	Clean jets Remove dirt in pipe Clean float needle valve Drain water from carburetor
Engine not receiving spark	No spark when wire is removed from plug and held close to cylinder	If in generator, look under "Generator troubles" If in battery, look under "Battery trouble" Broken wire: *Replace.* If magneto is used, adjust breaker points. Clean all leads
Engine not receiving spark	No spark when wire is removed from plug and held close to cylinder	Wipe out distributor Check up induction or transformer coil Check up condenser If necessary remove magnets and remagnetize
Engine not receiving spark	If spark is received when wire is removed from plug, and held close to cylinder	Remove plugs and clean Adjust spark plug gaps Examine for broken porcelain
Engine broken or parts broken	Sudden stoppage, accompanied by metallic sound	Replace all parts affected and examine for obstructions in oil pipes and cooling system

Note: A broken part is sometimes due to a flaw either in that particular part, or some part affecting its operation.

Q. 4. Name some troubles that cause loss of power and overheating, and give their remedy.

A. (1) Structure troubles:

TROUBLE	SYMPTOM	REMEDY
Excessive carbon	Knocking or preignition	Clean
Exhaust manifolds or pipes of insufficient capacity	Engine seems to drag	Either do away with the pipes or enlarge
Air leaks intake manifold	Engine does not idle well, "pops" and "drags" at high speed	Repair or replace
Bearings (connecting rod and main) tight	Overheating due to friction. Engine turns hard	Adjust by inserting shim
Crankshaft spring or journals grooved	Overheating due to friction.	Straighten in press, crocus or smooth up
Wrist pin loose, scores cylinder	Loss of power, due to loss of compression	Replace and fasten securely If necessary replace cylinder
Piston worn out of round, binding scoring cylinder	Loss of compression, overheating due to friction	Replace if possible, or smooth up
Piston rings worn out, grooves in line, losing spring	Loss of compression, gas blows by spark plug, soot	Replace, clean grooves
Camshaft or operating gear sprung, bearings worn, gears not meshed properly	Irregular valve action	Straighten, renew bearings, mesh gears, properly retime
Valve clearances too close or too far apart	Loss of power and sometimes overheating	Check and readjust
Valve stems worn, gummed or bent	Hissing	Straighten, and if necessary replace
Valve stem guides worn	Loss of compression	Either ream and bush or replace bushing
Valve blowing due to burning and warping	Hissing noise, loss of power and speed	Reseat and regrind and set clearances
Spark plugs leaking in threads	Hissing	Tighten, and if necessary replace gasket

2. Auxiliary troubles.

TROUBLE	SYMPTOM	REMEDY
Radiator filled with sediment	Overheating radiator will be hot in some places and cool in others	Clean out by boiling with lye solution
Water jackets and pipes clogged with dirt	Overheating—loss of power	Clean out
Water pump not working	Overheating and rattle	Repair shaft

Note: Sometimes the inner rubber or fabric of the hose becomes separated and causes an obstruction of the water passage.

TROUBLE	SYMPTOM	REMEDY
Not enough water in radiator	Radiator will boil very soon	Fill
Lubrication system not working	Overheating due to friction, oil temperature high, oil pressure too low or too high	Adjust oil pressure, clean lines, renew broken line
Carburetor trouble		Look under "Carburetor troubles"
Ignition trouble mostly caused by improper advance or timing	Loss of speed, overheating, loss of power (knock due to preignition)	Retime

Q. 5. Name some troubles that cause missing and poor operation, give remedy and divide under structure and operation.

A. 1. Troubles that cause missing and poor operation.

TROUBLE	SYMPTOM	REMEDY
Cylinder walls scored	Poor suction at intake manifold, oil leaks at exhaust valve	Regrind or replace, fitting new piston
Piston badly worn	(Same as above)	Renew
Piston rings worn, loose spring	(Same as above)	Renew
Carbon deposits on piston or in combustion chamber	Preignition (knock)	Remove cylinders and clean out carbon
Valve operating gear loose	Engine misses due to being out of time	Bush guides, renew tappets
Valve clearance too much or too little	One or more cylinders miss, according to the number of valves out	Readjust clearances
Valve springs broken or weak	(Same as above)	Replace
Valves blowing due to wear or burning	Missing and hissing sound	Regrind and adjust
Leaking intake manifold admitting air	Motor will not idle. Hissing sound	Renew gaskets and repair if necessary
Spark plugs not tight, broken or dirty	Cylinders "cutting out" regularly	Clean and tighten. Renew if necessary
Priming cock, loose in threads or jarred open	Motor will not idle well Hissing sound	Shut up and tighten if necessary
Twisted camshaft (rare)	Missing due to engine being out of time	Straighten if possible, if not renew. Retime

Note: Some camshafts are built up and not ground from a master cam. Set clearance by placing each piston in position of valve opening.

TROUBLE	SYMPTOM	REMEDY
Carburetor trouble	Missing, "popping" or "blowing" back	Adjust. See "Carburetors"
Ignition, loose wire or broken insulation. Ignition (if in generator or battery)	Missing	Look up under "Battery and generator troubles"
Dirty distributor blocks and contact points	Missing	Clean with gasoline or metal polish, smooth points and clean with fine brush

Q. 6. Name some troubles that cause knocking and noisy operation, giving their symptoms and remedy. Divide troubles under structural and auxiliaries.

A. 1. Structural troubles.

TROUBLE	SYMPTOM	REMEDY
Engine loose on bed	Very heavy knock or pounding	Tighten bolts
Propeller hub loose on flange	Same as above	Secure
Propeller out of track	Vibration due to propeller flutter	Line up, either by use of shims or facing hub
Main bearings worn, loose bolts	Sharp knock	Tighten bolts, remove shims or file off caps
Connecting rod bearings worn; loose bolts	Sharp knock	Tighten bolts, remove shims or file off caps
All bearings too tight	Squeaking—engine turns hard	Readjust
Wrist pin bushing worn	Very sharp knock	Re-bush and if necessary replace pin
Piston too loose or too tight	Slapping noise noticed at low speeds, squeaking	Refit, allowing proper clearance
Overheating, anything causing this will cause noisy operation	Knocking due to preignition	Remedy as directed before
Valve operating gear, loose, improper clearance, etc.	Clicking	Remedy as directed before

A. 2. Auxiliary troubles.

TROUBLE	SYMPTOM	REMEDY
Ignition spark not timed properly; too much advance or retard	Knock due to preignition, knock due to overheating, loss of speed	Retime
Carburetor too lean or too rich	Backfire, popping, knocking	Look under "Carburetors"
Lubrication, anything causing overheating	Knock or squeak; engine turns hard	Be sure that there is oil under proper pressure and that pipes are clear
Water service blocked, pump not working, no water, radiator filled with sediment	Knock due to overheating	As stated before

Note: Whenever a knock develops, it should be investigated immediately, the sooner the better, for if taken in time one may prevent damage to the entire structure.

Q. 7. Name some troubles that would cause hard starting or failure to start, giving their symptoms and remedy.

A. (Note): If the engine does not start after it has been primed and cranked a few times, it is advisable to look for the trouble. Remember it is unnecessary to stand and crank unless the engine shows some sign of starting.

1. Structural troubles.

TROUBLE	SYMPTOM	REMEDY
Engine turns very hard or holds fast		Look for frozen piston or bearing, or broken part
No compression	Engine will turn very easy	Look for sticking valves, worn rings or piston. No oil
Valve improperly timed		Retime

2. Auxiliary troubles.

TROUBLE	SYMPTOM	REMEDY
No gasoline, lines plugged with dirt, valve shut off. Jets plugged with dirt, water in gasoline	There will be no gasoline in float chamber. (If spark is good, failure to start is generally due to gasoline troubles)	Turn on valve, fill tank Trace trouble as directed under "Carburetors"
Primed too little or primed too much	Popping and blowing back	Prime or work excess fuel out by rotating engine backwards
Ignition	(If gasoline supply is O. K. and carburetor appears to be functioning properly, test ignitions	
Weak battery	No spark or weak spark and plugs. (No discharge shown with switch on)	Look up under "Battery troubles"
Loose or broken wire	Same as above	Check up wiring; renew broken wires
Oil soaked wires causing short circuit	Same as above	Clean wires; renew if necessary
Distributors soaked with moisture or dirty	Same as above	Wipe dry with soft rag. (It may be necessary to remove them and dry in an oven)
Burned out magneto windings, poor condenser	Same as above (arcing at breaker points)	Renew
Spark plug points not properly placed	Very weak spark or no spark at all when plug is removed and grounded on engine	Readjust
Wrong connections, i. e., leads to plugs out of place	Spark all right, still engine does not run (rare)	Check and place in proper position
Dirty plugs	Spark occurs when wire is removed from plug and grounded on cylinder	Clean plugs
Weak magnets (magneto)	Weak spark or no spark at all	Remagnetize

CHAPTER LV

The Liberty Aircraft Engine

Q. 1. Give a brief history of the Liberty engine.

A. The Liberty motor or the United States standard aircraft motor was developed for use during the war with Germany. It is a combination of the best features of aircraft engines that were in use at that time, and was designed by a group of aircraft engine designers who gave their product to the government. It was originally intended to produce this engine in four different models of four, six, eight, and twelve cylinders each, but advices from the front indicated that engines of great horsepower were required, so the twelve cylinder model was standardized, and manufactured by a number of the large automobile manufacturing concerns. All parts are interchangeable, and it was intended to keep a large stock of parts on hand and replace broken or damaged parts instead of repairing them.

Q. 2. Give a detailed description of the Liberty engine.

A. It is a twelve cylinder model with the cylinders set at an angle of 45°, and so designed to develop either 370 or 425 H.P. by simply changing the pistons. The motor developing 370 H.P. is the one used generally by the Navy, and is equipped with flat top pistons. The other type using a dome-shaped piston is used generally by the Army. The weight of the engine, not including radiator, propeller, fuel and oil tanks, is 806 pounds, the fuel consumption being about 30 to 34 gallons per hour, according to the engine, at wide open throttle. The oil consumption is about $1\frac{1}{2}$ gallons per hour at wide open throttle. The water pump and water

service (not including radiator) hold about $5\frac{1}{2}$ gallons of water. The Delco system, designed especially for this motor, is used. It consists of a storage battery, either Willard or Exide type, rated at 6 volts, 9 ampere hours, a specially designed 4 pole wave wound generator, two distributor heads, a special switch and voltage regulator. The entire ignition system weighs but 34 pounds 6 ounces. Two Zenith (U.S. 52) duplex carburetors fitted with a special altitude compensating device are used.

Q. 3. Describe the Liberty crankcase.

A. It is cast of aluminum in two halves, each half holding one-half of the bearings, in order to obtain rigidity. It is held together with sixteen large studs. The thrust housing is designed in such a manner as to allow it to be used either as a tractor or a pusher. The forward portion of the lower half is so shaped to hold the oil pump, and the after portion is fitted with a drain. The two halves of the case are lapped and fitted together to hold oil.

Q. 4. Describe the Liberty crankshaft.

A. It is forged and machined from a special heat treated steel, and has six throws set 120° apart. It is drilled hollow to eliminate weight and allow oil passage and rests in seven main bearings. It is fitted with a propeller hub on one and the main driving gear (for generator, oil pump, and valve driving apparatus on the other).

Q. 5. Describe the Liberty connecting rods.

A. The connecting rods are of the blade and fork type, the blade rod fitting on the crankshaft, and the fork rod over the blade rod. They are forged and machined from a special heat treated steel of I beam form.

Q. 6. Describe the Liberty piston.

A. It is of aluminum (Lynite), and so designed to carry the heat to the cylinder walls. It is fitted with three concentric rings. The wrist pin is not held stationary in the piston bosses, but allowed to float back and forth. Two aluminum piston pin retainers are pressed into the piston on either side of the end of the wrist pin and prevent the pin from scoring the cylinder.

Q. 7. Describe the Liberty cylinder.

A. The barrel is forged out of steel and the valve pockets welded in. The intake valve is on the inboard side and exhaust valve on the outboard side. The entire assembly is machined, and then the water jackets made of Russia iron (in two halves) are welded in place. The cylinders are numbered on the edges of the base flanges. They are held in place with 10 studs.

Q. 8. Describe the Liberty cooling system.

A. Cooling water is circulated by a centrifugal pump, running at $1\frac{1}{2}$ times engine speed, and capable of pumping 100 gallons of water per minute at full speed. The pump is provided with a single inlet of 2 inches outside diameter, and two outlets of $1\frac{1}{2}$ inches outside diameter. The water is forced in at the base of each cylinder jacket tangent to its outside surface which gives the water a whirling motion insuring uniform cooling The water outlet pipe extends inside the cylinder to a point close to the exhaust valve, which insures the proper cooling of this valve. From here the water is conveyed through passages cored in the intake header, where it assists in heating the mixture, and is cooled to some extent. The passages in the intake header are connected by two water outlet headers, the final outlet being 2 inches outside diameter.

Q. 9. Describe the Liberty oiling or lubrication system.

A. The oil for the Liberty engine is carried in two external tanks placed so as to act as coolers.

Note: In navy planes they are mounted on either side of the engine bed.

Oil is led from these tanks to the oil pump in the lower portion of the crank case through the connection on the right side of the pump marked "oil in." Here it is filtered by passing through a fine mesh screen. A gear type delivery pump takes the oil from the filter and passes it under a pressure not exceeding 50 pounds per square inch (controlled by a pressure regulating valve between the pump and main distributor pipe), through the main distributor pipe running the length of the crankcase.

The oil is then forced to the main bearings through pipes fitted in the case and leading from the main distributor pipe. The crankshaft is hollow and holes are drilled to allow the oil to pass from the main bearings into the shaft and out on the crank pin to oil the connecting rods. The oil is thrown off of the rapidly revolving rotating end of the connecting rod forming a spray which oils both the cylinder walls and the wrist pin.

Part of the oil led to the main bearings at the propeller end of the motor passes around this bearing and up through pipes to the propeller end of the camshaft housing, then through a passage around the bearing to a hole in the bearing. The camshaft is drilled to receive this oil and being hollow it carries it to each camshaft bearing. The excess oil working out of the bearings is held in a small reservoir at a depth of about $\frac{1}{4}$ inch. The revolving cams dip this oil and splash it over the rollers and into pockets in the rocker lever shafts, which are hollow, and convey it to the rocker shaft bearing. That portion of the oil left finds its way to the gear end of the camshaft housings, flowing over the gears and down the

drive shaft housing to a chamber just above the oil pump. The oil thrown off into the crankcase is also collected in this chamber when the engine is inclined, so that the propeller end is high. Another chamber is provided at the propeller end of the engine for the oil that drains to it when the propeller end of the engine is low. Another pump and oil return pump situated above the oil delivery pump, and driven by the same shaft, collects the oil through two inlets from these two chambers, and sends it to the two reservoirs or external tanks, through the connection on the left side of the engine marked "oil out."

Q. 10. Describe the Liberty camshaft.

A. The valves are operated by two overhead camshafts running in a cast aluminum housing. The camshaft is forged and machined from a special heat treated steel, the cams being forged integral with the shaft and ground from a master cam.

Q. 11. Describe the Liberty carburetor.

A. The Zenith Model U.S. 52 carburetor operating on the principle mentioned under carburetors is used on the Liberty engine. It is a duplex carburetor, which is equivalent to two carburetors, and as two of these are used, we have four mixing chambers, each one supplying three cylinders, and but two float chambers. The most important addition in this make of carburetor for the Liberty engine is the altitude adjusting device. The float chamber is open to the air through two screened air inlets, and the idling or compensating well is in open communication with the float chamber. There is also a passage connecting the float chamber and the mixing chamber, in which a manually operated stop cock is fitted, connected to an operating lever in the pilot's seat.

On the ground and at low altitudes this valve is closed, the carburetor functioning as described under carburetors, for the float chamber is open to the atmosphere. At altitudes above 6000 feet, this valve is opened and the suction in the mixing chamber creates a vacuum in the float chamber, through the medium of the connecting passage, thereby reducing the amount of fuel flowing out of this chamber. The reason for this is that the density of air decreases as the altitude increases.

Q. 12. Give a general description of the Liberty ignition system.

A. Ignition is supplied by a special Delco generator battery unit. Below a speed of 650 R.P.M. the current is drawn from the battery described under "Batteries;" above a speed of 650 R.P.M., the current is drawn from the generator. The output of the generator is regulated by a specially designed voltage regulator.

The regulator consists of an iron core on which are wound three coils, one magnetizing the core, another a reverse coil demagnetizing it, and the third a non-inductive resistance coil. By adjusting the tension of the spring the output of the generator is regulated. The regulation consists of weakening the field strength or the number of magnetic lines of force cut by the armature in the generator. A duplex switch is used and when either one of the switches is on, the current is drawn from the battery. When both switches are on, the current is drawn from the generator, the battery floating on the line. An ammeter is incorporated in the switch box and should show a 4 ampere charge while flying.

A Bakelite distributor head is fastened to both camshafts on the forward end of the engine. There are two main breakers and one auxiliary breaker in the line. The auxiliary breaker prevents backfiring.

The condenser and transformer coil are contained in the distributor head. The left distributor fires the plugs on the propeller end of the cylinder, and the right distributor fires the plugs on the gear end of the cylinder.

Q. 13. How would you disassemble, overhaul, and reassemble a Liberty motor? Give each step.

A. Order of tear down—Liberty motor:

DUAL IGNITION SYSTEM

a. Each distributor fires one plug in each cylinder throughout entire cylinders.

b. Right distributor fires plug on gear side of cylinder while the left fires propeller side.

c. Disconnect high tension conduit which is attached to outlet water header by cap screws with no washers.

d. Remove the 12 insulated wires fastened to spark plugs, being careful not to spring bell-clips. Rubber ferrules on end, must be in perfect condition to assure perfect insulation.

e. Remove distributor heads held by wire clips along with the conduit. Care should be taken to bind the brushes with a rag or rubber band to prevent breakage.

CAMSHAFT HOUSING ASSEMBLIES

a. Remove distributor tie-rods found in upper holes with boss down.

b. With snapper wrench remove collars on camshaft housings. A felt washer should be inserted in each collar to prevent oil leakage.

c. Loosen castle nuts on the 12 studs of each camshaft housing; plain washers are found under each nut.

d. Disconnect oil pipes leading to camshaft before removing camshaft assemblies which are marked either right or left.

e. Male splines on jack-shaft marked by a groove in one tooth.

f. Female spline carries two niches on collar. Both splines must coincide for timing.

g. Remove camshaft assembly by raising assembly squarely off of cylinders.

GENERATOR

a. Held by three castle nuts on studs. Plain washers. An oil paper gasket is found between generator pad and seat.

b. Only one bearing in generator.

c. Power connections not marked.

d. Splines must fit closely to prevent any back lash (come out rather hard).

CARBURETOR

a. Unfasten carburetor tie-rod. Purpose of tie-rod to make carburetors work simultaneously.

b. Watch taper pins that lock tie-rod.

c. Be careful of pins, easily lost.

d. Two copper asbestos washers separate each carburetor from manifold.

e. Although interchangeable, make each carburetor propeller end and gear end.

f. Each carburetor held by two anchor bolts with plain washers fastened to hot water intake head.

g. Remove water outlet headers before removing carburetors.

HOT WATER INTAKE HEADER

a. Held by four castle nuts with washers at each end having also two oil paper gaskets.

b. This part, with carburetor, remove practically at the same time, holding one in each hand.

MANIFOLD OR INTAKE HEADERS

a. Four in number, each held by six studs, castle nuts and washers, paper gaskets between each.

b. Each manifold stamped on exhaust flange-propeller end right or left and gear end right or left as the case may be.

c. Remove that manifold with smallest bearing surface first, found here to be right side.

d. Inspect manifold for loose cores which rattle.

WATER SYSTEM

a. Remove both outlet water pipes from pump. Right side is larger than left.

b. Remove inlet water headers; both pipes are interchangeable (hose bands).

c. Remove outlet water pipes of cylinders; loosen all hose bands attached to cylinder.

d. Three flanges attached to each manifold and held there by two cap screws through each flange having drilled heads. (Paper gaskets between manifold and each flange.)

e. Centrifugal pump—water pump—held by four studs with castle nuts, paper gaskets separate pump pad and seat.

f. Pump intake points to the left plugged hole found at the bottom.

BREATHERS (CRANKCASE)

a. Two crank case breathers on right side of engine, held by two nuts with paper gaskets.

b. Screened baffle at hole in case to prevent oil splashing out.

c. Wire strainer cloth under cap of each breather for pouring oil.

BREATHERS (GEAR END)

a. Held by two studs, washers and castle nuts, has paper gasket between, also baffle plate screen.

b. On the propeller end the three way distributor for oil is fastened by two castle nuts, washers and has an oil paper gasket.

CYLINDERS (TWELVE)

a. Start from gear or propeller end and remove flange nuts between each cylinder. Six other castle nuts serve to hold flange to cylinder pad.

b. Paper gaskets between cylinder pads and flanges are cut to cover three cylinders.

c. Remove one spark plug before pulling cylinder off piston to relieve vacuum.

d. Be sure cylinders are marked on flange below exhaust port.

PISTONS

a. Bind studs at base of cylinder pad to prevent scratching of pistons.

b. With pliers remove wire piston pin retainers.

c. Drive out piston with brass plug, pounding it gently.

d. Piston pin should only be driven far enough to clear pin housing.

e. Each piston is marked right or left and its number position.

f. Allow rings in grooves to remain untouched.

g. Rings are common split type with two right and one left. The splits being set at 180 degrees apart.

h. While removing piston pin hold piston firmly so as not to throw connecting rods out of line.

i. Be sure all pistons are marked on relieved surface toward gear end.

GENERATOR AND CAMSHAFT ASSEMBLIES

a. Remove gear case cap held by six cap screws drilled for wiring, no washers.

b. Remove jack shaft assemblies held by four stud castle nuts.

c. Should have a paper gasket between crankcase and pad.

d. Each shaft marked right or left on the beveled gear.

e. Ball race retainers in assembly.

f. These shafts must be removed before generator shaft, as gears of former prevent removal of latter.

REMOVE GENERATOR DRIVE SHAFT

a. Duty; to drive generator and two jack shafts.

b. Construction; with key-way in shaft for jack shaft gear, and two spacing sleeves to hold it where it belongs.

c. Bevel gear has twenty-two teeth.

TIMING

a. When 1 and 6 left are 10 degrees past dead center, splines should be placed in line with center of cylinder.

REMOVAL OF LOWER CRANK CASE

a. Loosen fourteen nuts on anchor bolts, a plain washer is found beneath each.

b. Turn crank case over allowing anchor flange to rest on wooden blocks mounted on frame.

c Remove two through bolts on end of each case. Also two anchor bolt nuts are found at propeller end and removed. Remove oil pump held by ten castle nuts with washers. A paper gasket is found between.

d. Remove fifty hexagon head bolts holding upper and lower crank cases together.

e. Lift off lower part of crank case.

REMOVAL OF SPOOL GEAR

a. Loosen set screw which holds assembly in place.

b. With case upright drive assembly through.

c. Upon measuring it will be found to be tapered .0007 inch over a distance of $2\frac{1}{2}$ inches.

FORK AND PLAIN END CONNECTING RODS

a. End play of connecting rods allowed .005 inch found to be as great as .016 inch.

b. Babbit metal bearing surface on fork rods bronze on plain end.

REASON

c. Plain end rod was removed first by turning shaft to allow it to let go easily upon removing nuts.

d. Forked rods followed, care being taken to place both halves of bearing surface as they originally were.

UPPER HALF CRANKCASE

a. Inspect bearing surfaces—high spots show up bright. (Should be a lead color throughout.)

b. Watch studs for loosening up.

c. Care should be taken to find any cracks or sand holes.

CRANKSHAFT INSPECTION

a. Inspect crank pins and main bearings for any scratches or rough spots. Crocus cloth will remove any slight scratches.

b. Teeth of driving gear on gear flanges should be perfect and not chewed up. Prick punched 12 degrees 30 minutes past center for timing purposes.

CAMSHAFT ASSEMBLY

a. Remove the six plates holding rocker arms in place, held by three hex. bolts and plain washers.

b. Withdraw bearing retainers which are set screws used to hold bearings in place.

c. Remove oil cap on gear end with a spanner wrench.

d. Remove 6 hex. nuts which hold distributor flange in place.

e. Withdraw camshaft with bearing attached.

f. Split bearing surface held by set screws—bearings are aluminum except at gear end, which is a bronze bearing.

CRANKCASE (UPPER HALF)

a. Place crankcase in inverted position.

b. Clean all bearing surfaces.

CRANKSHAFT

a. Clean all main and pin bearings.

b. Shaft, when seated, should have no end play.

CONNECTING RODS

a. Female connecting rods go to right cylinders in order indicated on "I" section.

b. Stamped surface should appear on gear side.

c. Numerals on bearing retainers, both halves, should correspond.

d. For male rods move shaft until rod enters female freely.

e. Position number on "I" section faces gear end.

f. Crank pin end of rod numbered, both halves of same should correspond.

BOLT CASES TOGETHER

a. Two through bolts on propeller and gear end drop into place and fastened.

b. Fifty hexagon anchor bolts placed and tightened to hold upper and lower cases together.

TURN CASE OVER

a. Tie connecting rods to stud with rags and invert.

b. Place hexagon nuts on the fourteen through bolts securing upper and lower crankcases.

MOUNT OIL PUMP

a. Fasten by 10 nuts, plain washers.

b. Paper gaskets between pad and flange.

c. Strainer in oil pump cap fastened by 3 nuts and plain washers, no paper gaskets found.

GENERATOR DRIVE SHAFT ASSEMBLY

a. Placed in position—fasten flange by three nuts and plain washers, no paper gaskets.

JACK SHAFT ASSEMBLY

a. Marked right and left on beveled gear—place as indicated.

b. When No. 1 and No. 6 cylinders, left side, are 10 degrees past dead center.

c. When No. 1 and No. 6 right are 10 degrees past dead center, marks on female spline should be on line with dead center.

GEAR END PLATE

a. Secured by six hexagon head set screws, whose heads are drilled for wiring.

JACK SHAFT FLANGES

a. Held by four hexagon nuts—no washers.
b. Threaded for camshaft collars.

WATER PUMP

a. Bolt water pump on lower crankcase with four nuts and plain washers.
b. Plugged hole at bottom.
c. Inlet from radiator faces to left.

PISTONS

a. Each piston is cleaned thoroughly and placed in position as stamped on side.
b. Piston pin is driven gently through piston and when in place wire retainers are set in grooves to hold pin in place.
c. The retaining clamps held in pliers—when compressed are dropped in groove.

CYLINDERS

a. Cylinder walls carefully cleaned.
b. Rings of piston compressed with hands to allow cylinder to pass over.
c. Cylinder held in place by nuts applied to skirt flange.

BREATHERS

a. Crankcase breathers.

b. Held by two stud nuts. Paper gaskets between.

c. Make certain wire strainer is held within crankcase wall and that strainer cloth is O.K. beneath cover.

d. Three-way oil pass on propeller end held by two nuts on studs. Paper gasket is used.

MANIFOLDS

a. Left manifold held in position with nuts tightened, while right manifold is wedged into place.

b. Left manifold has less bearing contact and therefore offers less obstruction to right manifold which has a greater bearing surface.

HOT WATER HEADERS

a. Secured to manifolds first before final tightening of manifold flanges.

b. This done in order to prevent any possible water leakage

CARBURETORS

a. Carburetors designed rear and propeller end.

b. Held in place by two bolts through hot water header and hang suspended between cylinders.

Q. 14. How would you time a Liberty engine? Give all steps in detail.

A. 1. If the timing disc is not already mounted on the propeller hub, install it in such a manner that the dowel in the propeller hub flange enters the dowel hole in the disc. It may be clamped in this position by means of two bolts through the propeller hub bolt holes.

2. Remove the spark plug from the propeller side of No. 6 L cylinder.

3. Insert a pencil or scale through the spark plug hole and turn the engine over until the piston on its up stroke touches the pencil and causes it to ride up. Continue to turn the engine over slowly until the piston as indicated by the travel of the pencil stops moving upward and is just about to start down. This will be approximately the top dead center.

4. Allow the crankshaft to remain in this position temporarily and clamp the timing pointers, which will be found in the tool kit, under the special cylinder base flange nuts, so that the pointers extend over the edge of the timing disc.

5. With the end of the pencil resting on the top of the piston make a mark with a knife blade about one-half inch above the edge of the spark plug hole.

6. Turn the engine over in a forward direction until the pencil has moved down so that the mark is even with the top edge of the hole, and with a piece of chalk or a pencil mark the disc in line with one of the pointers.

7. Turn the engine backward until the pencil has moved up and down to the point where the mark is again even with the top of the spark plug hole, and mark the disc in line with the pointer.

8. With a pair of dividers find the point midway between the two marks on the disc. This point will indicate the exact dead center of No. 1 and No. 6 cranks and should be marked with chalk or pencil.

9. Turn the engine over until this dead center mark is in line with the pointer. Allow the crankshaft to remain in this position and,

10. Reset the pointers so that they come in line with the dead center marks stamped on the disc.

11. Turn the engine over in the direction of rotation through ten degrees as indicated by the scale on the disc. The crankshaft is now set on the neutral point of No. 6 left cylinder and the firing point—spark retarded of No. 1 left cylinder. "Neutral point" is the point ten degrees past the top dead center which marks the beginning and end of the cycle of operations. The exhaust valve closes and the inlet valve opens at this point.

Mount the generator drive shaft assembly, being careful that the gasket is in place and a sufficient number of shims (.002 inch thick) to insure proper mesh of the generator drive shaft lower gear with the crankshaft gear. These gears should have a minimum back lash of 0.005 inch and a maximum of 0.010 inch.

Mount the two camshaft drive shafts, meshing the gears in such a manner that the mark on the splined couplings is "fore" and "aft" or parallel with the center line of the engine.

Now mount the camshaft housing assemblies.

If it was not found necessary to replace either the camshaft or gear, be sure that the marked teeth on both gear and pinion are in line. This should bring the mark on the splined end of the drive shaft "fore and aft."

The assemblies may now be set in place with the splined coupling marks in line.

Note: All marks for both right and left cylinders are located with No. 1–6 cranks ten degrees past left dead center.

Complete the installation of these assemblies by replacing the washers and the nuts and properly cotter pinning them.

Slip the felt washers into place and tighten up the stuffing boxes.

Test the gap between all tappets and the valves which they operate. The tappet gap for each cylinder should be

checked when that cylinder is on the firing point. The firing point of No. 1 cylinder is the neutral point of No. 6 on the same side. The firing point of No. 2 is the neutral point of No. 5. The firing point of No. 3 is the neutral point of No. 4. The firing point of No. 4 is the neutral point of No. 3. The firing point of No. 5 is the neutral point of No. 2. The firing point of No. 6 is the neutral point of No. 1. It will be noticed that the sum of the numbers of these pairs of cylinders is always seven. For example—to find the firing points of No. 4 cylinder, turn the engine over, meanwhile watching the No. 3 exhaust valve. When this valve has just closed and before No. 3 inlet valve has opened, the neutral point of No. 3 cylinder will have been reached. This will be the firing point of No. 4. With the engine cold the clearance between the inlet valve tappets and the valve stems should be 0.014 to 0.016. The clearance between the exhaust valve tappets and valve stems should be 0.019 to 0.021. This clearance should be adjusted by adding or taking out shims under the tappet head. These shims are made in varying thicknesses, the thick shim being 0.015 inch thick, the medium shim being 0.008 inch, and the thin shim being 0.003 inch. The combination of these shims will permit of a very accurate adjustment of the gap. Be sure that the shims are properly placed and that the nuts on the tappets are tightly drawn up and cottered.

If it was found necessary to replace either the camshaft or the camshaft gear, proceed as follows:

1. With No. 1–6 crank set ten degrees past the left dead center, the marked splines on the camshaft drive shaft set "fore and aft," the marked splines on the upper camshaft drive shaft in line with them, the marked tooth on the upper camshaft drive shaft gear should be toward the observer and on the center line of the cylinders.

2. Without moving any of this assembly rotate the left camshaft in a clockwise direction until the No. 6 exhaust valve is just closed and the inlet valve is just about to open.

3. Now mesh the camshaft gear in such a manner that the teeth and the flange bolt-holes will line up perfectly.

The camshaft gear has 48 teeth and is bolted to the flange by means of seven bolts. This will permit an adjustment of one-seventh of one tooth space or two and one-seventh degrees crankshaft travel.

4. Tighten up two of the camshaft gear bolts and check the tappet clearance on all left cylinders.

5. Now check the opening and closing of the exhaust and inlet valves. If it is found that the valves are late in opening and closing, the number of degrees should be noted and the camshaft gear moved one or more holes in the direction of rotation without moving the camshaft drive shaft or the camshaft. Remember that for each hole move forward, the camshaft is advanced two and one-seventh degrees of crank shaft rotation. If the valves are found to open early, set the camshaft gear backward one or more holes.

Always check valve timing by turning engine in forward direction of rotation so as to take up all back lash in gears and lost motion in couplings.

After the gear has been properly located, set the left distributor driving flange over the bolts in such a position that the marked notch is in line with the marked tooth on the drive pinion.

Now tighten up and cotter pin the bolts and mark the gear in line with marked tooth on the drive pinion.

To set the right camshaft, turn the engine over in the direction of rotation through 45 degrees or until the No. 1 crank is ten degrees past the right dead center. With the crankshaft in this position turn the camshaft over in a

clockwise direction until the No. 1 exhaust valve is just closed and the inlet valve is just about to open. Locate the gear in the same manner as in setting the left camshaft.

Before mounting the right distributor driving flange, turn the crank shaft back through 45 degrees or to its original position and set the distributor drive flange so that the marked notch comes in line with the marked tooth on the drive pinion, or in other words, in line with the center line of the right cylinders.

Now tighten up the camshaft gear bolts and cotter pin as before.

Set the two distributor assemblies in place, being careful to get them on the proper housings right and left.

These distributors are marked R and L on the outside surface of the spark control arms. They should be fastened temporarily by means of two bolts, each in such a position that the notch on the distributor base flange coincides with the notch on the camshaft housing flange.

If it has been found necessary to replace either the camshaft housing or the distributor head, and the new parts do not carry these identifying notches, the distributor should be so set that with the spark retarded the center line of the cylinders will be midway between 1 L and 6 R terminals.

1. Set the engine on the firing point, spark retarded, No. 1 L cylinder, in other words, the neutral point of No. 6 L.

2. Swing the timing lever on the distributor to the full retarded position or as far in a clockwise direction as is possible.

3. Loosen the bolts sufficiently so that the distributor base flange can be rotated on the slotted holes.

4. Connect battery and electric light across the distributor terminals, and rotate the distributor base flange

in a counter clockwise direction until the light just goes out. Tighten the bolts with the distributor in this position and complete the installation of the bolts.

5. Without changing the position of the crankshaft install and set the right hand distributor in a similar manner.

6. The accuracy of the timing should now be checked up by rotating the crankshaft backward 15 or 20 degrees, then forward very slowly, meanwhile watching the electric lights. They should both go out at the same time within a limit of one and one-half degrees on the timing disc. If the pocket flashlight is used instead of the two electric lights and battery, each distributor head will have to be checked separately and the time of the break noted according to the timing disc.

7. Install the cross reach and adjust it so that both distributor heads will be fully retarded. Check the synchronization of the two distributor heads with spark lever in advanced position also.

8. Install the high tension cable tube and cable assembly, fastening it by means of the screws to the intake headers.

9. Wire the heads of all these screws so that they will not loosen up.

Caution: Care should be exercised in placing the distributor head assembly on the distributor to keep from breaking the rotor brush. It can best be done by putting the distributor head assembly over the two studs, and slightly rocking it back and forth with the rotor in the right angle position to the center line of the two studs. This will gradually work the brush into the rotor and allow the distributor head to slip down into place.

Q. 15. What precaution must be taken when testing a Liberty motor?

A. If the engine being tested is designed for use in high altitudes, it is equipped with dome top pistons. It should not be run on stand with the throttle more than one-half

to two-thirds open. With these dome pistons the compression is excessive at low altitudes, and if run at open throttle, a break down will result. Engines fitted with flat top low compression pistons may be run on the stand with wide open throttle.

CHAPTER LVI

Hispano-Suiza Engine

Q. 1. Give a brief description of the Hispano-Suiza engine.

A. The model "A" Hispano, used for N-9 training seaplanes in the navy, develops 150 H.P. at 1450 R.P.M. at sea level. It is V type water cooled 4 cycle engine; cylinders 120 mm. (4.72 inches) bore by 130 mm. (5.11 inches) stroke, set at an angle of 90 degrees. It is equipped with the Zenith carburetor and two Dixie No. 800 magnetos, and has a separate hand starting magneto.

The engine without propeller, fuel, oil, water and tanks weighs 470 pounds.

The firing order is 1 L—4R, 2 L—3R, 4 L—1R, 3 L—2R. This engine uses about 15 gallons of gasoline per hour, at full speed, and $\frac{3}{4}$ gallon of oil also at full speed. The water pump is capable of delivering about 26$\frac{1}{2}$ gallons per minute at wide open throttle. The valve clearance is 2 mm. or 0.078 inches.

Q. 2. Describe the Hispano-Suiza cylinder block and cylinders.

A. The individual cylinders are steel forging, heat treated, machined and threaded on the outside. These sleeves are flanged at the bottom and closed at the top, this surface being flat, providing for the two valve seats. The cylinders or sleeves are screwed into a cast aluminum block which forms the water jackets, valve ports, intake and exhaust passage.

Q. 3. Describe the Hispano-Suiza piston.

A. The piston is of cast aluminum $\frac{3}{8}$ inch thick at the head. The sides taper from $\frac{3}{8}$ inch at the top to $\frac{1}{8}$-inch thickness at the bottom. This construction insures a rapid disposition of the heat. There are four narrow rings in two grooves at the top. There is one oil ring near the bottom with a relief just below it. The wrist pins or piston pins are hollow and made of case-hardened alloy steel. They are allowed to float in both sides of the piston and upper end of the connecting rod, but are kept from scoring the cylinders by a piston pin lock ring.

Q. 4. Describe the Hispano-Suiza connecting rods.

A. They are made of heat treated steel, tubular in shape. One rod is forked and is fitted to the crank pin; the other a blade rod is fitted on to the forked rod. Both of these rods are provided with bronze bushings at the upper end.

Q. 5. Describe the Hispano-Suiza crank shaft.

A. It is of the 4 throw type, throws spaced equally 180 degrees apart. It is made of chrome nickel steel machined all over, and is bored hollow for lightness and to allow oil passage. The shaft rests in four plain main bearings, and an annular ball bearing at the gear end. There is a thrust bearing at the propeller end suitable for either a tractor or pusher.

Q. 6. Describe the Hispano-Suiza crank case.

A. The crankcase is of cast aluminum, made in two halves, each half holding one half of the main bearing. The lower half is of very deep section, thus providing an oil reservoir and at the same time stiffening the engine.

Q. 7. Describe the Hispano-Suiza cam shaft.

A. The camshafts are hollow and supported by three main bearings. They are driven by two sets of bevel gears, and two vertical shafts from the crankshaft at one half times its speed. These vertical shafts are fitted with screw driver joints in order that the cylinder assembly may be removed easily. The camshafts and valve stem heads are all enclosed in an oil tight aluminum removable housing. The valve housing is fitted with an air pressure pump, the piston of which is operated by one of the cams.

Q. 8. Describe the Hispano-Suiza valve gear.

A. The valves are set vertically in the cylinders along the center of each block, and are directly operated by a single camshaft. They are made of Tungsten steel with large hollow stems working in cast iron bushings, provided at the upper end with case hardened flat headed adjusting screws or discs, upon which the cams operate. Two springs are used, either one strong enough to close the valve if the other breaks. The clearance adjustment between the adjusting screws and cams is obtained by the use of serrated washers. These washers are pressed upward by springs and hold the adjusting screw in place while they permit easy turning by means of a special wrench, which angularly displaces the adjusting screws in the stems of the valves. The spring retainer washer is held in place angularly by means of tenons which engage slots in the stem. Nevertheless, the whole assembly can slide freely lengthwise. The valve spring holds the spring retainer to the adjustment disc, the rim of which is arranged with small indentations.

Q. 9. Describe the Hispano-Suiza lubrication system.

A. The oiling system of the Hispano is known as a positive force or pressure system. A sliding vane eccentric pump mounted vertically and directly below the gear end

of the camshaft in the lower half of the crankcase, is driven by the same gear that drives the camshaft driving shafts at 1.2 times engine speed. This pump forces the oil through a filter in the lower half of the crankcase, and then through steel tubes cast in the crankcase to 3 of the main bearings to the hollow crankshaft to crank pin oiling both connecting rods. The spray thrown off of these rapidly revolving rods oil the cylinder wall, piston pin and piston. The fourth or front main bearing has an oil lead which takes care of the lubrication of the main bearing, and in addition to this has a by pass around the outside of the bearing which carries the oil to two tubes running up the front end of the cylinder blocks. This tube carries oil to lubricate camshaft and bearings, valve tappets and stems, vertical shafts and bearings, and the driving gear. The oil is forced into the front end of the hollow camshaft, and out through holes oiling all the parts within the upper housing, and then down through the vertical shaft housing and back to the sump.

Q. 10. Describe briefly the disassembly, repair and assembly of an Hispano-Suiza engine.

A. All navy aircraft engines must be torn down, checked and if necessary repaired after every 75 hours flight.

1. The motor is fitted to the overhaul stand and torn down as follows:

a. Remove ignition wires and distributor blocks intact.

b. Remove magnetos marking their position.

c. Remove camshaft housing and camshaft, marking position on gears.

d. Remove all exterior oil connections, gear housings, and cylinder studs.

e. Remove all manifolds and carburetor.

f. Remove cylinders.

g. Remove piston pin retainer, piston pin and piston.

2. Turn engine on stand 180 degrees or upside down.

a. Remove lower half of crankcase.

b. Remove crankshaft, placing on a separate stand.

c. Remove connecting rods from crankshaft.

3. Place cylinders on bench.

a. Remove valves and regrind.

4. Place sump on bench.

a. Remove water pump.

b. Remove oil pump.

c. Remove oil filter.

d. Remove oil pressure relief valve.

5. Inspect all parts of the disassembled engine, repair, or replace such parts that are worn or defective, weigh parts, and reassemble by starting the last operation of disassembly first, and so on.

Q. 11. How would you time an Hispano-Suiza engine?

A. 1. Secure degree plate on crankshaft.

2. Revolve until upper dead center of L No. 1 cylinder is found.

3. Turn shaft until degree plate shows piston to be 10 degrees past upper dead center in the direction of rotation.

4. At this point attach camshaft and mesh gear so that inlet valve is just opening and exhaust just closes. (Note valve clearance must be 2 mm. or 0.078 inches).

5. Rotate the shaft 90 degrees further in the direction of rotation and set No. 4 R cylinder cams the same as No. 1.

6. Set magnetos to break on firing cylinder 20 degrees 20 minutes before top dead center.

Q. 12. What precaution must be taken when operating Hispano-Suiza engines?

A. The valves run hot in these engines, and must be

watched constantly. If there is a sign of valve leaking, the valves should be reground immediately. In flight the motor should not be accelerated too quickly or idled too often, for this has a bad effect on the valves.

Q. 1. Describe briefly the Union aircraft engine.

A. This engine is used for lighter-than-air work on account of its power at low speed, endurance, and ability to idle well. It is of six cylinders in line, firing order L.H. engine 1, 4, 2, 6, 3, 5,—R.H. engine, 1, 5, 3, 6, 2, 4. It is equipped with two Zenith carburetors L B. jet 140, compensator 165, well 70, choke 31 (setting). Ignition equipment, two Dixie No. 612 magnetos, Bethlehem aviation spark plugs (metric). Lubrication system is force feed from an external tank mounted below the sump. Water circulation by centrifugal pump, capacity of which is 30 gallons per minute open throttle. Maximum speed 1400 R.P.M.

TOP OVERHAUL OF ENGINES AFTER STORAGE

All engines that have been in storage or unused in machines for more than three months since previous running, as recorded in the log book, should be subjected to top overhaul before being passed by the ground engineer for flight. The internal condition of the engine should be carefully examined for signs of corrosion, particular attention being paid to cylinder bores and all ball and roller bearings.

In addition to the usual precautions taken after top overhaul to ensure that all parts of the engine, including ignition and carburetor systems, function correctly, special attention should be given to the flushing of all oilways—flushing, cleansing, adjustment, refilling, etc., of lubricators, filters, etc.

CHAPTER LVII

ROUTINE INSPECTIONS

Q. 1. What routine inspections should be carried out by aircraft engine mechanics?

A. They are as follows:

I. Daily inspection.

Note: Aircraft should be moved either to the run way or to a suitable place on the beach for testing, and the castors of the truck blocked.

a. Inspect all visible bolts and nuts.

1. See that they are properly drawn up and securely locked.

b. Test engine for internal trouble.

1. Turn propeller by hand, noting the following:

   a. Listen for piston slap.

   b. Listen for excessive gear lash or clearance.

   c. Listen for any loose bearings.

2. If possible move propeller up and down.

Note: If thrust bearing is loose in housing, it can be heard.

c. Inspect propeller mounting.

1. See that hub flange bolts are drawn up and securely locked.
2. See that the retaining nut and lock are drawn up tight, and be sure that the tongue of the lock wire passes through both.
3. Check pitch and track of propeller.

d. Inspect throttle and spark controls.
   1. See that throttle control of carburetor synchronizes.
   2. See that throttle control at pilot's seat permits full throttle opening.
   3. See that the spark control at pilot's seat permits full range of retard and advance.

e. Inspect all electrical connections and ignition units.
   1. See that all wire terminals are properly soldered, clear, and firmly attached to the distributors, generator, battery, switch and voltage regulator.
   2. Wipe all wires, and clean all terminals.
   3. See that all wires are supported at the proper intervals, and in such manner that the insulation will not be abraded.
   4. Check distributors, see that rotor path is clean and that the breaker points are functioning properly.

f. Inspect all gasoline tanks and supply lines.
   1. See that tanks are full.
   2. Inspect all tanks for leaks.
   3. Inspect all lines for leaks.
   4. Inspect the sediment trap for leaks.

g. Check cooling system carefully.
   1. See that the radiator is full of water.
   2. Inspect pump for leaks, particularly the packing gland.
   3. Inspect all water service piping for leaks, particularly all hose connections.
   4. Inspect all jackets for leakage particularly around exhaust valve.

h. Inspect lubrication system.
   1. See that both tanks (Liberty engine) have sufficient quantity of oil.
   2. Inspect all oil piping for leakage, particularly hose connections.

i. Start engine noting the following:
   1. Speed in R.P.M. full throttle.
   2. Water temperature (not to exceed 190° F.).
   3. Oil pressure.
   4. Oil temperature.
   5. (Liberty engine) cut each switch in order to ascertain whether or not each distributor is functioning.

II. Weekly inspection.

a. This should include the above, and in addition the following:
   1. Check valve clearances.
   2. Check compression of each cylinder, by turning engine over with propeller.
   3. Check friction of each cylinder by turning engine over with propeller.
   4. Inspect all spark plugs; remove and clean them.

III. Before flight.

a. Check spark and throttle controls.

b. Inspect wiring and switches.

c. Inspect fuel, oil and water supply.

d. Inspect all pipes for leakage.

IV. After flight.

a. Same inspections as Before Flight, and in addition the following:
   1. Propeller mounting and tips.
   2. All external bolts and nuts.

CHAPTER LVIII

Lubricating Oils, Tests, Etc.

Lubricating oils are classified as follows: (1) Mineral oils, (2) fixed oils, (3) blown or thickened oils, (4) rosin oils, (5) lubricants containing soap, greases, (6) deflocculated graphite—Aquadag and Oildag.

Mineral Oils are extensively manufactured from crude petroleum and shale oil. They contain a great variety of hydrocarbons, the lightest of which compose crude naptha from which gasoline, petrol and motor spirit and similar products are obtained. These liquids are devoid of lubricating properties. They are highly inflammable and are used for driving motors, dry cleaning, solvents, etc. Hydrocarbons of higher boiling point and specific gravity which are too fluid and volatile for use as lubricants are utilized to manufacture kerosene, petroleum, paraffin oil, etc. The heaviest and least volatile hydrocarbons are alone used in the manufacture of lubricating oils, paraffin wax and vaseline. The refiners separate the various products from the crude oil and purify them for use, this being done by distillation and chemical treatment. The value of distillation depends upon the fact that the different constituents of the crude oil boil and volatilize at different temperatures, the naptha coming off first, illuminating oils second, then intermediate oils from which illuminating oils are made by same being destructively distilled, leaving the heaviest hydrocarbons in the still; by separate fractional distillation, the naptha is subsequently split up into gasoline, etc., and the remainder into lubricating oils of various grades, paraffin wax, and asphalt or coke.

Fixed Oils. Fixed oils, so-called because they are not volatile without decomposition, are found ready formed in certain tissues of animals and plants. Fixed oils include such oils as castor, rape, lard, cottonseed, whale, etc.

Blown or Thickened Oils. The blown oils used for lubrication are usually rape or cottonseed oils, which have been artificially thickened by forcing a current of air through heated oil.

Rosin Oils. Rosin oil is obtained from the destructive distillation of common rosin.

Lubricants Containing Soap, Grease. Such lubricants are artificially thickened by dissolving soap in minerals—used for cup and engine greases.

Deflocculated Graphite. Aquadag and Oildag. A paste of deflocculated graphite and water, known as "Aquadag" is added to lubricating oil in a mixing machine, the water being thrown out leaving the graphite in a paste form. Oildag added to mineral oil increases the lubricating value of oil where solid friction exists.

TESTS FOR LUBRICATING OILS

1. Gravity, Baumé, at 60° F.
2. Flash, Cleveland open cup.
3. Fire, Cleveland open cup.
4. Viscosity, Saybolt Universal viscosimeter, at 100°, 150°, and 212° F.
5. Pour test as described below.
6. Acid.

Specific Gravity

Apparatus. Set of hydrometers.

Method. The hydrometers as supplied in the field testing outfit are marked with the specific gravity direct.

Since all specific gravities are comparable at 60° F., the results should be reported in degrees Baumé at 60° F.

Flash and Fire Test

The flash point is the degree of temperature at which ignitable volatile vapors are given off by the oil, producing a flash when brought in contact with a small flame. The fire test is a continuation of the flash test until the oil permanently ignites.

Apparatus. The apparatus for the flash and fire test consists of the following:

a. Cleveland open-cup tester, as recommended by the Bureau of Mines.

b. Alcohol lamp or gas burner.

c. Thermometer with range to 600° F., corrected for bulb immersion.

d. Wax tapers or gas jet.

Method. This test shall be made in the Cleveland open-cup tester, the apparatus being used without any bath or outer cup surrounding the oil cup. The oil cup should have two marks on the inside—the first, $\frac{1}{4}$ inch below the top, and the second $\frac{3}{8}$ inch below, the first to be used when testing oils with a flash point below 425° F., and the second when testing oils with a flash point at or above 425° F. The clean oil cup should be inserted into the tripod ring, which must be level, and the cup filled to the proper mark with the oil to be tested. Care should be exercised not to spill any oil on the sides or top of the cup, and if this accident should happen, all such oil must be carefully removed.

A "bulb immersion" thermometer should then be inserted into the oil, and suspended from a suitable support. The bulb of the thermometer should be $\frac{3}{8}$ to $\frac{5}{8}$ inch in length. During the test the bulb must be fully covered by the oil

and the bottom of the thermometer must not be less than $\frac{1}{4}$ inch from the bottom of the cup. The thermometer must be suspended in the oil midway between the center and inside edge of the cup. The alcohol or gas burner is then placed under the oil cup so as to heat it uniformly. The oil may be heated rapidly at first, but the rate of heating should be 8° to 10° F. (5° C.) per minute during the last 80° of heating prior to attaining the flash point. As the flash point is approached, a test is made for every 5° F. rise in temperature (on the readings which are multiples of 5) by slowly passing a small bead-like test flame, or lighted wax taper, not exceeding $\frac{1}{8}$ inch in length, across the center of the cup $\frac{1}{4}$ inch above the surface of the oil, the movement occupying one second.

The temperature when a flame first jumps from the test flame to the oil is called the flash point of the oil. The test must be made where the cup is free from draft and must be made in a subdued light.

After the flash point has been obtained, the same method of testing shall be continued until the oil takes fire and continues to burn. The temperature at which the oil continues to burn is the fire point of the oil.

To extinguish the fire after the fire point has been taken, remove the thermometer and alcohol lamp and then place the lid over the burning oil.

Viscosity Test

Apparatus. *a.* Saybolt standard universal viscosimeter.

b. Stop watch.

c. Thermometers. Range 270° F.

Method. Viscosity shall be determined by means of the Saybolt standard universal viscosimeter, as described in the *Proceedings of the American Society for Testing Materials,* Vol. XIX, Part 1, 1919.

Viscosity shall be determined at 100° F. (37.8° C.), 130° F. (54.4° C.) or 210° F. (98.9° C.). The bath shall be held constant within 0.25° F. (0.14° C.) at such a temperature as will maintain the desired temperature in the standard oil tube. For viscosity determinations at 100° and 130° F., oil or water may be used as the bath liquid. For viscosity determinations at 210° F., oil shall be used as the bath liquid. The oil for the bath liquid should be a pale engine oil of at least 350° F. flash point (open cup). Viscosity determinations shall be made in a room free from drafts and from rapid changes in temperature. All oil introduced into the standard oil tube, either for cleaning or for test, shall first be passed through the strainer.

The outer bath is filled with a paraffin engine oil with a flash of about 350° to 400° F., and the temperature is adjusted by letting cold water flow through the U-tube or by heating, as may be necessary. The tube, which incloses a small jet, is closed by a cork, which is inserted just far enough to be air-tight and not nearly far enough to touch the jet. The oil, previously strained into a tin cup and heated to about the required temperature, is poured into the tube until it overflows and fills the cup above the level of the upper end. It is then stirred with a thermometer until the temperature is exactly adjusted. The thermometer is withdrawn and the surplus oil is removed from the gallery by a pipette. The cork is then withdrawn and the number of seconds occupied in filling the flask to the 60 cc. mark is noted by a stop watch and recorded as the viscosity in seconds.

Pour Test

The pour test indicates the temperature at which a sample of oil in a cylindrical container of specified diameter and length will just flow under specified conditions.

Apparatus. The apparatus for the pour test consists of the following:

a. Glass jar, approximately $1\frac{1}{4}$ inches inside diameter and 4 to 5 inches high, provided with a tightly fitting cork.

b. Mercury thermometer, fitted securely in the cork so that the shaft will be held centrally in the jar with the tip of the bulb $\frac{1}{2}$ inch from the bottom. The thermometer specially made for this test has a bulb $\frac{1}{4}$ to $\frac{3}{8}$ inch long.

Method. Place the oil in the jar to a depth of about $1\frac{1}{4}$ inches or to a sufficient depth to reach $\frac{1}{4}$ inch above the bulb of the thermometer; fit the cork tightly into the jar and place the jar in a freezing mixture. At each drop in temperature of 5° F. remove the jar from the freezing mixture and tilt it just enough to make the oil flow. The pour test of the oil shall be taken as 5° higher than the reading of the thermometer when the oil has cooled so that it will not flow when the jar is tipped to a horizontal position.

The rate of cooling should be such that the pour test will be completed in about one-half hour.

The materials used in the freezing mixture vary with the temperature required to cause the lubricant to solidify. Cracked ice will be sufficient for a temperature above 35° F. For temperatures between 15° and 35° F. a mixture consisting of 1 volume of salt and 20 volumes of ice may be used. The salt for this purpose should be very dry and fine enough to pass a 20-mesh screen. From 15° to −5° F., ice and salt in the proportions of 1 to 2 are suitable. From 0° to −25° F. a mixture of ice and calcium chloride is used. For temperatures lower than −5° a mixture of solid carbon dioxide and acetone is more convenient and will produce temperatures of −70° F. or less.

The carbon dioxide-acetone mixture may be made as follows: Place a sufficient amount of dry acetone in a covered copper or nickel beaker; place the beaker in an ice-salt mixture, and when the acetone reaches 10° F. or less, add solid carbon dioxide gradually until the desired temperature is reached.

To obtain the solid carbon dioxide, invert an ordinary liquefied carbon-dioxide cylinder, open the valve carefully, and let the gas flow into a chamois-skin bag. Rapid evaporation will cause the carbon dioxide to solidify.

Acidity Test

Acidity in oils is generally due to a partial decomposition of the oil with liberation of fatty acids. These latter act as corrosive agents, attacking the metal of machinery, forming "metallic soaps," and producing gumming and thickening of the lubricant.

Properly refined mineral oils are free from acidity, but nearly all animal and vegetable oils possess it more or less.

Lubricating oils should be neutral and show no trace of acids.

Apparatus. Litmus paper.

Method. Rub a small quantity of oil on a piece of polished brass or copper. The metal must not turn green after standing for twenty-four hours.

Another method to determine the acidity of an oil is to wash a small quantity of the oil with distilled water, then drain off the water and place a piece of litmus paper in the water. If the litmus paper turns red, acid is present; if the paper turns blue, alkali is present; if there is no change, the oil is neutral. The paper should remain unchanged.

CHAPTER LIX

Oil Reclamation

Oil taken from the crankcase of internal combustion engines usually contains considerable free carbon in suspension, dirt, grit and possibly some water.

Generally, too, in the case of gasoline or kerosene engines, some of the heavy ends of the gasoline or kerosene have leaked past the piston rings into the oil, thus contaminating it and reducing its viscosity to such an extent as to make it unfit for further use in engines.

Laboratory and running tests made by the United States Bureau of Standards have demonstrated beyond a doubt that oil does not wear out. The oil does accumulate the impurities mentioned above, which render it unfit for long continued use; but if these impurities are removed entirely, and the body of the oil brought back to its original viscosity, the reclaimed oil can be used again in the engines from which it was taken with exactly the same satisfactory results as if new oil was used.

As a matter of fact these tests have shown that reclaimed oil deposits less carbon in an engine than the same oil when new. Certain constituents which tend to form carbon deposits are thrown out of the oil during its use in an engine. The process of reclaiming this oil really refines it, removing these carbon forming elements.

The Oil Reclaiming Plant at the Naval Air Station, Pensacola, Florida, is equipped with three Richardson Phoenix purifiers with a daily capacity of 375 gallons. With intermittent operation, the cost of reclamation is estimated at ten cents per gallon, which would be materially reduced

by a capacity production. Dirty oil is dumped into a vat on the unloading platform outside the plant, from whence it flows by gravity to the dirty oil tanks inside the building. From these tanks it is delivered by service oil pumps to the purifiers. Here by the introduction of live steam the oil is agitated and volatiles driven off.

If the oil to be reclaimed contains more than ten per cent gasoline, this can be profitably reclaimed by condensing the fumes driven off during agitation of the oil. The length of time necessary to agitate the oil with steam depends entirely upon the brand of oil, the amount of dirt and volume of gasoline or kerosene in it

The duration of agitation must be determined by actual experiment. Samples may be drawn off at any time and subjected to a flash test.

When the flash point of the sample has been brought as high as the flash point of the same oil when new, it is evident that the steaming has been carried on long enough to drive off the gasoline and kerosene ends.

The average maximum steaming time is one hour with steam at 30 pounds pressure.

After steam agitation has been completed, from $\frac{1}{8}$ to $\frac{1}{4}$ of a pound of soda ash or sal soda for each gallon to be treated, should be thoroughly dissolved in sufficient water to obtain a saturated solution and the solution mixed with the oil.

The function of the soda is to coagulate the carbon and other suspended impurities in the oil.

It is not necessary to add water to used motor oils when being purified. Sufficient water is naturally added by steam condensation during agitation and with the soda solution.

After introducing the soda solution, the mixture is again agitated for a period of about fifteen minutes to assure a thorough intimate mixture of the soda solution with the oil.

The oil is now allowed to settle. A period of ten hours is usually sufficient.

After settling process has been completed the mixture is divided into three layers. At the bottom is a layer of water. Above this is a layer of "sludge." On top is the clean oil.

The oil is removed from the purifier by displacing it with water. It should be drawn off at a temperature of not less than 120° F. Piping leading to storage tank is thoroughly flushed and the clean oil drawn off into the clean oil storage tank, ready for issue.

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